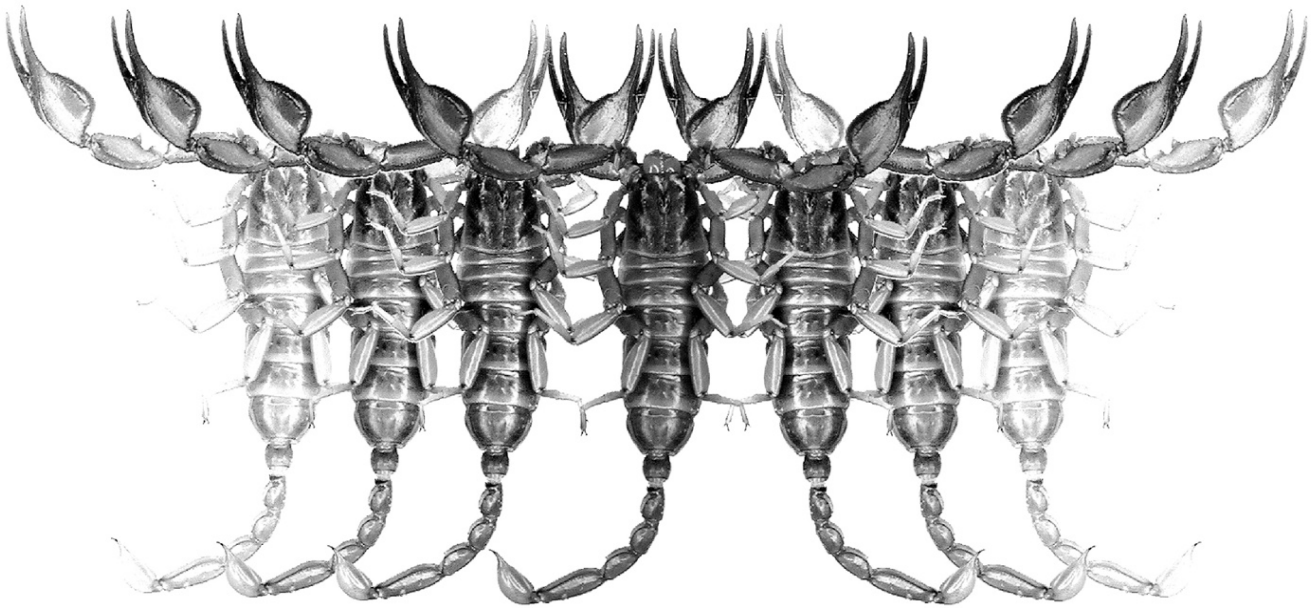


Euscorpius

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**Two new cryptic species of
Isometrus (Scorpiones: Buthidae)
from the northern Western Ghats, India**

Shauri Sulakhe, Nikhil Dandekar, Anand Padhye & Deshabhushan Bastawade

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Two new cryptic species of *Isometrus* (Scorpiones: Buthidae) from the northern Western Ghats, India

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<http://zoobank.org/urn:lsid:zoobank.org:pub:3FBC1884-2400-479B-8A26-94A92CAD64D0>

Summary

Integrated taxonomic approach is used to describe two new cryptic species of the genus *Isometrus* Ehrenberg, 1828 (Scorpiones: Buthidae) from the northern Western Ghats of India. *Isometrus tamhini* sp. n. and *I. amboli* sp. n. are closely related to each other and differ from two other Indian species of the genus, *I. thurstoni* and *I. maculatus*, by the morphological features and a raw genetic divergence of over 10%.

Introduction

The family Buthidae C.L. Koch, 1837, comprises 96 genera and over 1,170 species of extant scorpions distributed worldwide (Rein, 2020). Only two species belonging to the genus *Isometrus* Ehrenberg, 1828, are currently found in India: the type species, *Isometrus maculatus* (DeGeer, 1778) and *I. thurstoni* (Pocock, 1893) (Kovářik, 2003). *Isometrus sankeriensis* Tikader & Bastawade, 1983, previously described from India, was synonymized by Kovářik (2003) with *I. thurstoni*. The subgenus *Isometrus* (*Reddyanus*) Vachon, 1972 was recently elevated to genus level by Kovářik et al. (2016); therefore there are no valid subgenera in the genus *Isometrus* s.str. at this moment.

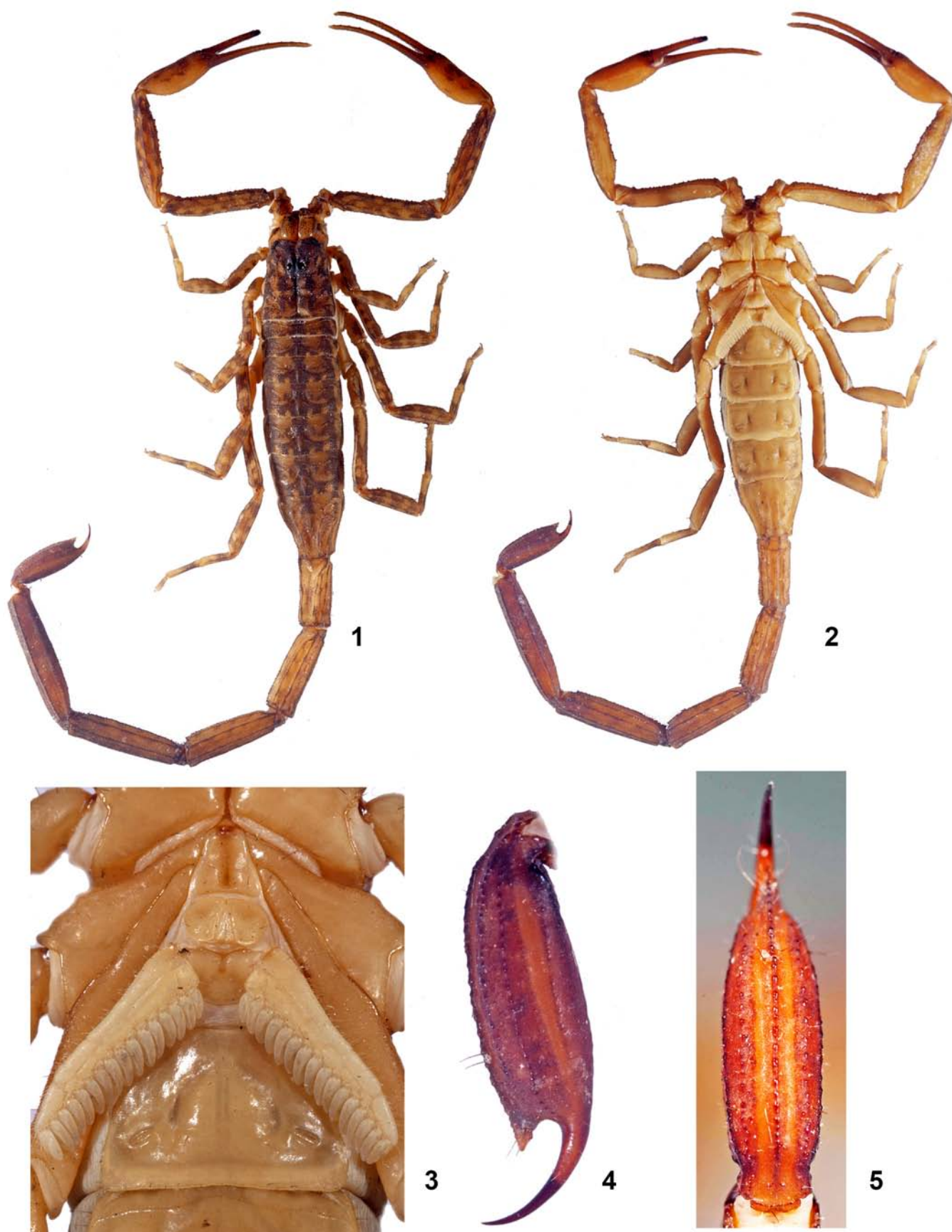
Isometrus thurstoni was described from the type locality of Shevaroy Hills (India) and is distributed in the states of Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra and Tamil Nadu (Pocock, 1893; Tikader & Bastawade, 1983; Fet & Lowe, 2000) and in Sri Lanka (Pocock 1900). *I. maculatus* is a cosmopolitan species found in India and 70 other countries. In India, it is recorded in the states of Maharashtra, Karnataka, Tamil Nadu, West Bengal and Meghalaya (Kovářik, 2003; Fet & Lowe, 2000). Fet et al. (2003) and Suranse et al. (2016) published limited molecular phylogenies of the family Buthidae but the genus *Isometrus* was not a part of those studies. Most of the molecular studies in scorpions have suggested that many previously described species are complexes with related species that are cryptic, i.e. species, which are not easy to distinguish based on morphology as opposed to deep genetic divergence (Mirshamsi et al., 2010).

During an extensive survey of northern Western Ghats, we encountered two populations of *Isometrus*, which were morphologically and genetically different from their congeners. In this study, we provide the first molecular phylogeny along with morphological comparisons of the species of the genus *Isometrus* found in India, with description of two new species.

Methods, Material & Abbreviations

Sampling was carried out in Dongarwadi (18.48°N 73.41°E, 638 m a. s. l.) near Tamhini and Amboli (15.94°N 74.00°E, 872 m a. s. l.) in the northern Western Ghats of India. Specimens were located with the help of ultraviolet light (The Scorpionator, Scorpion Master model), and collected. Photographs of holotype and paratype were taken using a Nikon D90 DSLR camera, 105mm F2.8 macro lens and R1 flash kit. Specimens were euthanized and preserved in absolute ethanol, and later transferred to 70% ethyl alcohol in collection jars for long term preservation. Examination and morphological measurement were done using a LEICA EZ4HD stereo microscope with the LEICA application suite. Morphometry was performed following Stahnke (1971) and morphological terminology follows Hjelle (1990). Morphometric measurements were taken (in mm) for 38 morphological characters (Table 1). The trichobothrial terminology follows Vachon (1974).

Specimens collected and studied are deposited in the Bombay Natural History Society, Mumbai, India (BNHS); Institute of Natural History Education and Research, Research Laboratory, Pune, Maharashtra, India (INHER); and California Academy of Sciences (CAS), San Francisco, California, USA.



Figures 1–5: *Isometrus tamhini* sp. n., male holotype **Figures 1–2.** Dorsal (1) and ventral (2) views **Figure 3.** Sternopectinal area. **Figures 4–5.** Telson in lateral (4) and ventral (5) views.

*Comparative material examined:**Isometrus thurstoni* (Pocock, 1893)

India, Tamil Nadu State, Salem, Shevaroy Hills, 11.84°N 78.19°E, 1194 m a. s. l. 4♂ (INHER-134, 136, 139, 141), 4♀ (INHER-130, 132, 135, 137), 27 August 2019, leg. S. Sulakhe, M. Ketkar, S. Deshpande & M. Kulkarni; 1♂ (CAS-ASU-1797.1), leg. P. S. Nathan.

Isometrus maculatus (DeGeer, 1778)

India, Karnataka State, Mysore District, Chikmagalur, 1♀ (CAS-20.II.1962), 1♀ (CAS-21.II.1962); Kerala State, Idukki District, 42 km N of Munnar, Marayoor, 1♀ (CAS-1.IV.1962), West Bengal State, Howrah District, Khalishani, leg. Mrs. Isa Santra & Rec. Mr. Banerjee, 1♂ (CAS-66-486, 6-10-66); Bangladesh ("E. Pakistan"), Chittagong Division, Baraiyadhala Forest Reserve, leg. S. Ross & D. Q. Cavagnaro, 1♀ (CAS-IX-21-61).

STATISTICAL ANALYSIS

A discriminant function analysis (DFA) using Principal Component Analysis (PCA) factor was conducted to assess the degree of morphological differentiation among the new species and their closest relatives. In order to nullify the influence of body size, PCA were performed using 16 size-corrected morphometric parameters (Table 2) taken from adults of both sexes. Sets of 16 predictor variables were generated from PCA and all PCA factor scores were used as input variables for DFA to determine the classification success of our samples (Garg et al., 2017). PCA and DFA were performed using the statistical software PAST 3.25 (Hammer et al., 2001).

MOLECULAR ANALYSIS

For the genetic analyses, whole genomic DNA was extracted from preserved (99.9% ethanol) muscle tissue (leg fragment) of *Isometrus tamhini* sp. n., *I. amboli* sp. n. and *I. thurstoni*, (Voucher numbers of specimens used for DNA analysis are listed in Table 6 and Fig. 61) with the help of MACHEREY-NAGEL NucleoSpin® DNA Insect kit as per manufacturer's protocols. A 550-600 base pair (bp) fragment of the cytochrome c oxidase subunit I (*COI*) mitochondrial gene was amplified by polymerase chain reaction (PCR) using the primers LCO1490 and HCO2198 (Folmer et al., 1994). A 25 µl PCR reaction (TaKaRa Taq™ DNA Polymerase) was set containing 1 unit of Taq DNA polymerase (0.2 µL), 2.5 µL of 10x buffer, 2 µl of dNTPs (2.5mM each), 2 µl (5mM) of each primer, 2µl template DNA, and 14.3 µl of water, carried out with an Miniamp Thermal Cycler. Thermal cycler profiles used for amplification were as follows: 95° C for 3 min (denaturation temperature 95° C for 30 seconds, annealing temperature 50° C for 30 seconds, elongation temperature 72° C for 1 minute) x 35 cycles, 72° C for 7 minutes, hold at 4° C. PCR product was cleaned through column purification method with Barcode Biosciences PCR Cleanup Kit and sequenced with a 3730 DNA Analyzer. The sequencing primers were the same as those used in the PCRs. All sequences were deposited in the GenBank nucleotide sequence database (<http://www.ncbi.nlm.nih.gov>) under accession numbers as per (Table 6).

The sequences were also checked on the Blast tool to find the closest available sequences and the related ones were downloaded for analysis. Gene sequences were aligned using MUSCLE (Edgar, 2004). Molecular phylogenetic analysis was performed using MEGA 6 (Tamura et al., 2013). Pairwise raw phylogenetic distances were calculated in MEGA 6 (Tamura et al., 2013). The best fit model for nucleotide substitution was selected from 24 models using MEGA 6 (Tamura et al. 2013) based on the minimum Bayesian Information Criterion (BIC) value (Schwarz, 1978; Nei & Kumar, 2000). The best fit nucleotide substitution model was used for testing the phylogenetic hypothesis using maximum likelihood method. Phylogenetic tree was built using MEGA 6 (Tamura et al., 2013) and reliability of the tree was estimated using bootstrap values from 1000 replicates.

Systematics

Family Buthidae C. L. Koch, 1837

Genus *Isometrus* Ehrenberg, 1828

(Figure. 1–61, Tables 1–6)

Isometrus (selected references): Pocock, 1893: 297; Pocock, 1900: 44 (in part); Vachon, 1972: 169; Tikader & Bastawade, 1983: 254 (in part); Kovařík, 1994: 189 (in part); Fet & Lowe, 2000: 146 (in part; complete reference list until 1998); Kovařík, 2003: 1 (in part); Kovařík & Ojanguren, 2013: 180 (in part).

TYPE SPECIES. *Scorpio maculatus* DeGeer, 1778

Isometrus tamhini sp. n.

(Figures 1–14, 36, 40, 46, 50, 54, 58, Tables 1a, e, 2–6)

<http://zoobank.org/urn:lsid:zoobank.org:act:08F3D798-CB85-4F5D-B823-D980B4A8EAAB>

TYPE LOCALITY AND TYPE REPOSITORY. India, Maharashtra State, Pune District, Tamhini, Dongarwadi, 18.48°N 73.41°E, 638 m a. s. l.; BNHS.

TYPE MATERIAL. **India**, Maharashtra State, Pune District, Tamhini, Dongarwadi, 18.48°N 73.41°E, 638 m a. s. l., 1♂ (holotype, BNHS SC 155), 27 October 2018, 1♂ (paratype, INHER-73), 30 October 2018, 1♂ (paratype INHER-92), 2♀ (paratypes INHER-91 and INHER-94), 27 October 2018, 1♀ (paratype BNHS SC 156), 1♀ (paratype INHER-78), 23 October 2018. All specimens collected by S. Sulakhe, R. Yenpure, C. Risbud & M. Ketkar.

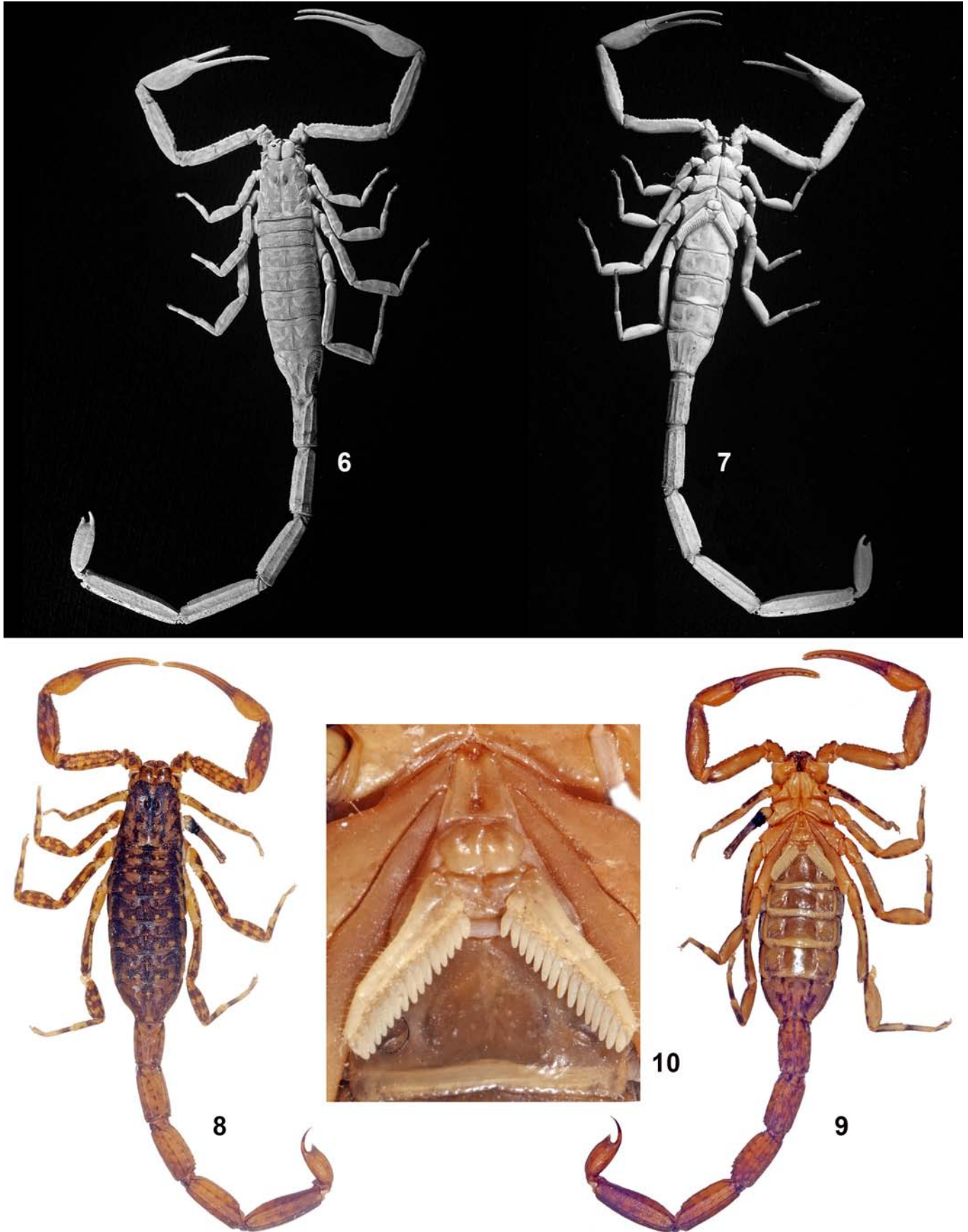
ETYMOLOGY. The species epithet is a noun in apposition indicating the Tamhini Village located in the Pune District, northern Western Ghats, the type locality of the new species. Suggested common name: Tamhini Tree Scorpion.

DESCRIPTION. (♂ holotype, measurements in Table 1a)

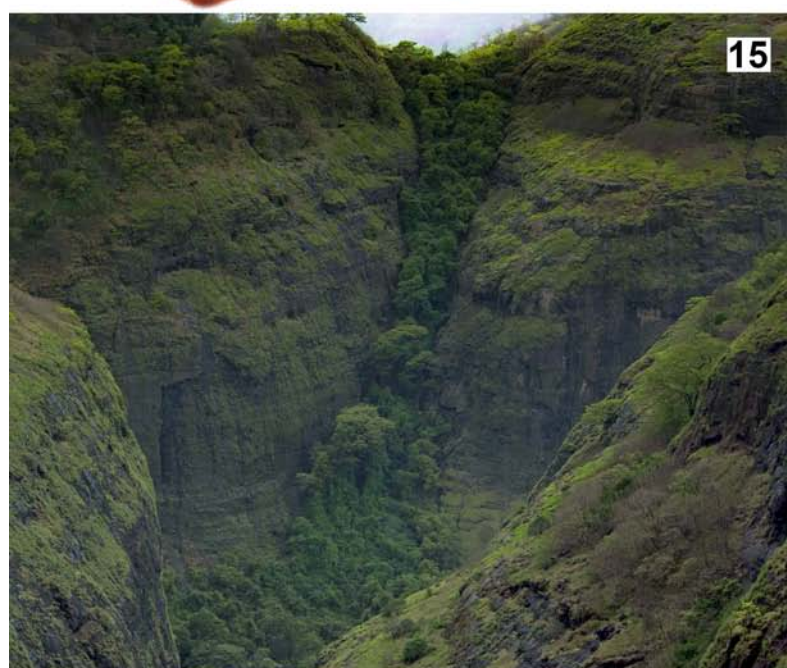
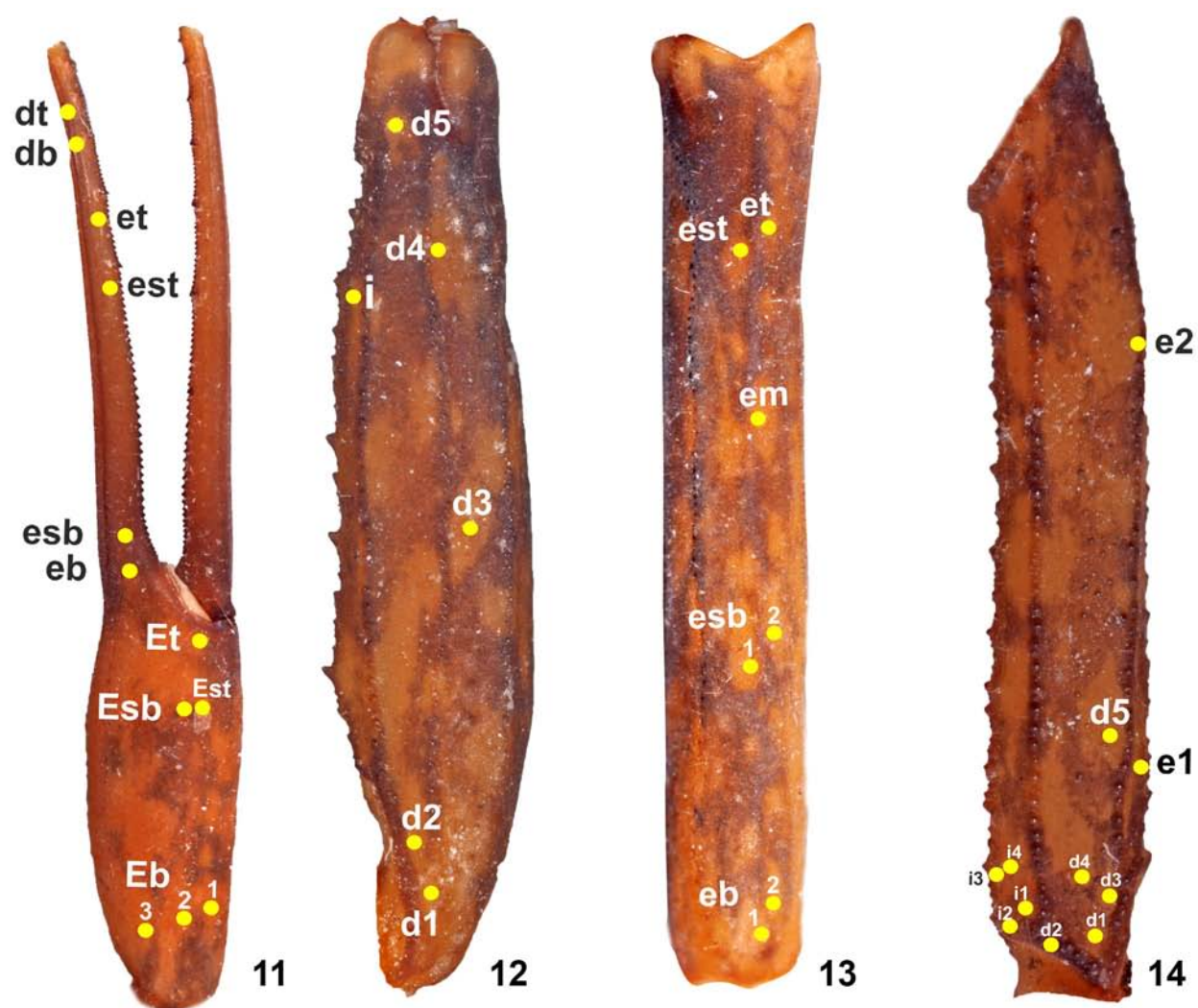
Dimensions (mm)		<i>I. tamhini</i> sp. n. ♂ HT-BNHS SC155	<i>I. tamhini</i> sp. n. ♂ PT-INHER92	<i>I. tamhini</i> sp. n. ♂ PT-INHER73	<i>I. tamhini</i> sp. n. ♀ PT-INHER91
Carapace	L / W	5.0 / 4.0	4.8 / 3.8	4.6 / 3.8	4.0 / 3.5
Mesosoma	L	15.4	14.6	12.6	10.0
Tergite VII	L / W	4.1 / 4.4	3.9 / 4.2	3.6 / 4.0	2.7 / 4.1
Metasoma + telson	L	45.2	42.7	40.8	25.3
Segment I	L / W / D	4.3 / 2.1 / 2.0	4.1 / 2.0 / 2.0	3.9 / 2.0 / 2.0	2.6 / 2.0 / 1.8
Segment II	L / W / D	5.6 / 1.8 / 2.0	5.2 / 1.7 / 2.0	4.6 / 1.7 / 1.7	3.3 / 1.8 / 1.9
Segment III	L / W / D	6.0 / 1.8 / 1.9	5.5 / 1.7 / 1.8	5.4 / 1.7 / 1.7	3.4 / 1.6 / 1.7
Segment IV	L / W / D	7.0 / 1.7 / 1.8	6.4 / 1.6 / 1.8	6.2 / 1.7 / 1.6	3.9 / 1.5 / 1.7
Segment V	L / W / D	8.2 / 1.7 / 1.9	7.5 / 1.5 / 1.9	6.8 / 1.7 / 1.6	4.3 / 1.4 / 1.7
Telson	L / W / D	7.1 / 1.6 / 1.8	7.1 / 1.5 / 1.8	6.9 / 1.5 / 1.7	3.9 / 1.2 / 1.3
Telson aculeus	L	2.1	2.3	2.3	1.7
Pedipalp	L	26.5	25.6	23.8	16.1
Femur	L / W	7.3 / 1.3	7.0 / 1.2	6.7 / 1.2	4.3 / 1.2
Patella	L / W	7.6 / 1.6	7.2 / 1.5	6.9 / 1.5	4.7 / 1.4
Chela	L	11.6	11.5	10.4	7.1
Manus	L / W / D	5.1 / 1.9 / 1.5	4.7 / 1.8 / 1.6	4.2 / 1.7 / 1.4	2.4 / 1.4 / 1.3
Movable finger	L	7.0	6.9	6.5	5.1
Pectine	L / W	3.8 / 0.8	3.5 / 0.9	3.4 / 0.8	2.9 / 0.6
Total	L	58.4	55.0	51.0	35.4

Dimensions (mm)		<i>I. tamhini</i> sp. n. ♀ PT-INHER94	<i>I. tamhini</i> sp. n. ♀ PT-BNHS SC156	<i>I. tamhini</i> sp. n. ♀ PT-INHER78
Carapace	L / W	4.3 / 2.9	4.2 / 3.2	4.3 / 3.7
Mesosoma	L	8.9	11.5	9.9
Tergite VII	L / W	2.5 / 3.9	2.9 / 4.6	2.5 / 4.2
Metasoma + telson	L	26.2	26.4	28.8
Segment I	L / W / D	2.9 / 2.0 / 1.9	2.9 / 2.1 / 2.0	2.8 / 2.2 / 1.9
Segment II	L / W / D	3.4 / 1.8 / 1.8	3.4 / 1.8 / 2.0	3.5 / 1.9 / 1.9
Segment III	L / W / D	3.6 / 1.7 / 1.9	3.8 / 1.8 / 1.9	3.7 / 1.7 / 1.9
Segment IV	L / W / D	3.7 / 1.7 / 1.7	4.0 / 1.8 / 1.9	4.1 / 1.6 / 2.0
Segment V	L / W / D	4.8 / 1.4 / 1.7	4.2 / 1.6 / 1.9	4.4 / 1.6 / 1.8
Telson	L / W / D	4.0 / 1.3 / 1.3	4.1 / 1.4 / 1.3	5.2 / 1.2 / 1.4
Telson aculeus	L	1.9	2.0	2.1
Pedipalp	L	16.7	17.7	18.0
Femur	L / W	4.2 / 1.4	4.6 / 1.2	4.7 / 1.3
Patella	L / W	4.7 / 1.4	5.0 / 1.5	5.2 / 1.6
Chela	L	7.8	8.2	8.1
Manus	L / W / D	2.7 / 1.3 / 1.2	2.7 / 1.4 / 1.3	2.9 / 1.4 / 1.3
Movable finger	L	5.2	5.6	5.4
Pectine	L / W	2.8 / 0.7	2.6 / 0.7	3.0 / 0.8
Total	L	35.4	38.1	37.9

Table 1a: Morphometric data for *Isometrus tamhini* sp. n. Abbreviations: length (L), width (W), depth (D), holotype (HT), paratype (PT).



Figures 6–10: *Isometrus tamhini* sp. n. **Figures 6–7.** Male holotype in dorsal (6) and ventral (7) views, UV image. **Figures 8–10.** Female paratype, BNHS-SC-156, in dorsal (8) and ventral (9) views, and sternoplectinal area (10).



Figures 11–16: *Isometrus tamhini* sp. n. **Figures 11–14.** Male holotype, Pedipalp chela external (11), patella dorsal (12), and external (13), and femur in dorsal (14) view. Trichobothrial pattern indicated by yellow circles. **Figures 15–16.** Type locality of *I. tamhini* sp. n., a dense semi-evergreen forest of Tamhini and Dongarwadi.

Coloration (Figs. 1, 2, 8, 9). Body and appendages yellowish brown and variegated with blackish brown stripes and spots; metasomal segment V and pedipalp fingers dark brownish. Ventral portion of the body uniformly yellow and posterior one-third portion of sternite V light yellowish to whitish. Basal segments of chelicera dorsally yellowish with blackish reticulation ending anteriorly into brownish transverse patch; Ventral surface of chelicera yellowish; fingers of chelicera dark brown. Telson blackish brown.

Carapace (Figs. 6, 36, 40). Surface densely and coarsely granular, almost entirely except few areas on lateral and posterior median portion. Carapace without carinae, except for a pair of conspicuous median supra-ocular carinae; with coarse granular texture. A pair of median eyes situated anteriorly in the ratio 1:2.2 (ratio of median eyes to anterior margin and median eyes to posterior margin). Anterolateral ocular tubercle granular, with three pairs of sub-contiguous lateral ocelli and two micro-ocelli situated behind the lateral ocelli. Median longitudinal furrow throughout the length of carapace. Anterior margin with shallow emargination coarsely granulated with conspicuous median notch. Lateral margins finely and densely crenulated below the lateral ocelli. Posterior margin almost entirely smooth, except for the latero-posterior portion.

Chelicerae. Characteristic of the family Buthidae. Basal segments and movable fingers with short and firm setae on the basal and ventral surfaces.

Pedipalp (Figs. 11–14). Femur with 5 carinae (dorsal exterior, dorsal interior, exterior median, interior median and exterior ventral). Exterior median carina with few granules more prominent, robust and triangularly tuberculate. All remaining carinae are evenly crenulated. Intercarinal space more granular on dorsal surface. Ventral surface almost smooth except few closely set granules on proximal portions. Patella with 7 distinct carinae (dorsal median, dorsal interior, dorsal exterior, exterior median, ventral exterior, interior median and ventral interior). Dorsal exterior, dorsal interior and dorsal median weakly granular. Dorsal interior supported with an additional short carina on anterior sub-dorsal portion. Interior median strongly tuberculated with few sub-denticulate granules. Exterior median, ventral exterior and ventral interior carinae smooth and obsolete. Intercarinal space weakly and finely granular. Manus without carinae and finely and sparsely granular. Fixed fingers with 2 smooth and obsolete carina (dorsal exterior and dorsal interior). Fixed and movable finger armed with 5 rows of linear dentition. Trichobothrial pattern typical for the genus.

Legs. Femur and patellae carinated. All carinae granular. Tibiae 3 and 4 without tibial spur. All legs with a pair of pedal spurs. Tarsomere covered with long delicate setae arranged in parallel rows on ventral side. Tarsomere I with a tuft of short, stout blackish setae. Tarsomere II compressed laterally. Dorsal margin of each leg ending into a pointed projection and ventrally provided with paired row of short, pointed, anteriorly directed, closely placed setae. Tarsomere II armed with a pair of sharply pointed curved claws and a soft, triangular and blunt basal claw.

Genital operculum (Figs. 3, 10). Wider than long, elliptical, separated, with a pair of short male genital papillae.

Pectines (Figs. 3, 10). Basal piece rectangular, deeply notched on anterior median margin. Posterior margin of basal piece slightly curved; smooth on surface with a parallel wide sub-basal piece along the posterior margin. Surface provided with pairs of short, red setae. Pectines 4.5 times longer than width, marginal lamella of 3 digits and median lamella of 6 digits, external margin armed with a row of stout short red setae and few setae on surface. Fulcra number 15, roughly triangular each armed with few short red setae, placed in between adjacent pectinal teeth. Teeth number 16, strong and stout.

Mesosoma (Figs. 1–3, 6–9). Tergites I–VI sparsely and finely granular and with a granular median carina. Posterior and lateral margins granular. Tergite I with short median carina. Tergite VII narrow posteriorly, granular, provided with 2 pairs of lateral granular carinae, inners up to pre-tergal portion while external pair runs diverging laterally up to two-thirds portion and end abruptly. A broad median carina limited to anterior one-third of median portion. Sternites III – VI almost entirely smooth with a pair of spiracles; with very finely granular on posterior margins, other margins smooth, each tergite with different numbers of setae on surface and posterior margins. Sternite V with extended, convex, exceptionally smooth posterior median margin. Sternite VII smooth on posterior margin while finely crenulated to serrated on lateral margins; with 2 pairs of granular carinae; median carinae restricted to posterior two-thirds portion; lateral carinae present in the middle portion.

Metasoma (Figs. 1–2, 6–9). All segments longer than wide; basal segment two times longer than wide. Segment I with 5 pairs of carinae (dorsals, dorsolaterals, laterals, ventrolaterals and ventrals) well developed and granular, ending posteriorly in a sub-triangular blunt and weakly pointed tubercle. Intercarinal space weakly and finely granular, anterior margin granular. Segments II and III provided with 4 pairs of carinae (dorsal, dorsolateral, ventrolaterals and ventrals). Laterals granular and marked on posterior one-third portion of II and III segments. Intercarinal portion irregularly granular, dorsolateral and dorsal carinae posteriorly ending in to subtriangular tubercles. Segment IV with 4 pairs of granular carinae (dorsal, dorsolateral, ventrolaterals and ventrals). Dorsals ending into subtriangular tubercles. Intercarinal space less irregularly granular. Segment V with 7 carinae (dorsal, dorsolateral and ventrolateral pairs and single ventral); dorsal carinae weakly, sparsely and obsoletely granular. Dorsolaterals present throughout. Laterals totally absent. Ventrolaterals and single ventral median carinae granular and ending posteriorly into weakly granular anal rim. Intercarinal space irregularly and weakly granular than segments I–IV.

Telson (Figs. 4–5, 54). Vesicle elongated, smooth on dorsal surface. Lateral surface demarcated with granular ridge. Ventral median carina strongly granular ending into triangular, subaculear tooth, armed with a pair of minute denticles on inner margin. Ventral portion with 2 pairs of sparsely and finely granular carinae. Intercarinal space weakly and finely

granular. Aculeus with strong acute angle between subaculear tooth and base of aculeus. Subaculear tooth more pointed and external margin along the ventral median carina almost straight with the vesicle.

SEXUAL DIMORPHISM. Male genital operculum partially exposed on posterior portion, from which a pair of small genital papillae is seen. In females, the genital operculum is separated with a median suture covering the female genital orifice (Figs. 3, 10).

AFFINITIES. *Isometrus tamhini* sp. n. is distinguished from its congeners based on the following set of characters:

1) Surface of carapace densely and coarsely granular as opposed to densely and finely granular in *I. amboli* sp. n., granular throughout but obsolete in *I. maculatus*, as opposed to sparsely granular with some areas without granules in *I. thurstoni* (Figs. 36–39). **2)** External margin of subaculear tooth of telson along the ventral median carina, almost straight with the vesicle (Fig. 4). **3)** Pedipalp length more than 5 times the carapace length in males as opposed to less than or equal to 5 times in males of *I. thurstoni*, *I. amboli* sp. n., and *I. maculatus* (Table 1e). **4)** Anterior margin of carapace with shallow emargination as opposed to anterior margin of carapace with deep emargination in *I. thurstoni* (Figs. 56–59). **5)** Telson depth to telson length ratio is equal to or more than four times in males as opposed to less than four times in *I. amboli* sp. n. and *I. thurstoni* (Table 1e). **6)** Telson aculeus less elongated in males (telson length 3 times or more than 3 times telson aculeus length) as opposed to telson aculeus more elongated (telson length always less than 3 times telson aculeus length) in males of *I. amboli* sp. n. and *I. thurstoni* (Table 1e, Figs. 52–54). **7)** Ventral median carina on vesicle strongly granular as opposed to very weakly granular in *I. thurstoni* (Fig. 5). **8)** Pectine length less than 5 times pectine width as opposed to pectine length greater than 5 times pectine width in *I. maculatus* (Table 1e).

DISTRIBUTION, HABITAT AND ECOLOGY. The new species is currently known only from the type locality. In our primary surveys, the specimens were found on tall trees in the semi-evergreen forests of Tamhini and Dongarwadi. All the specimens were found on large trees with rough bark having ridges, at a height of 2 to 4 meters (Figs. 15–16, 34–35).

***Isometrus amboli* sp. n.**

(Figures 17–31, 37, 41, 47, 51, 55, 59, Tables 1b, e, 2–6))

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TYPE LOCALITY AND TYPE REPOSITORY. India, Maharashtra State, Sindhudurg District, Amboli, 15.94°N 74.00°E, 872 m a. s. l.; BNHS.

TYPE MATERIAL. India, Maharashtra State, Sindhudurg District, Amboli, 15.94°N 74.00°E, 872 m a. s. l., 11 May 2019, 1♂

(holotype, BNHS SC 157), 06 September 2017, ♂ (paratype, INHER-42), 11 May 2019, 1♀ (paratype, BNHS SC 158), 5♂ (paratypes, INHER-110, 111, 112, 113, 114, 115), leg. S. Sulakhe.

ETYMOLOGY. The species epithet is a noun in apposition indicating the name of the Amboli Village located in Sindhudurg District, northern Western Ghats, where the type locality is situated. Suggested common name: Amboli Tree Scorpion.

DESCRIPTION. (♂ holotype, measurements in Table 1b)

Coloration (Figs. 17–18, 24–25). Body and appendages dark brown and variegated with blackish brown stripes and spots; dark brownish last metasomal segment and pedipalp fingers. Ventral portion light yellowish except sternite VII with darker patches. Sternite V with pale yellowish color (Fig. 18). Basal segments of chelicera dorsally yellowish with blackish reticulation ending anteriorly into brownish transverse patch; Chelicerae dark brownish on anterior portion of basal segments and fingers. Telson reddish brown in color.

Carapace (Figs. 37, 41). Surface densely and finely granular, almost entirely except very few areas without granules on the posterior median portion. Carapace without carinae, except for a pair of inconspicuous median supra-ocular carinae, with fine granular texture. A pair of median eyes situated anteriorly in the ratio 1:2.1 (ratio of median eyes to anterior margin and median eyes to posterior margin). Anterolateral ocular tubercle granular, provided with 5 pairs of lateral ocelli. Three pairs of sub-contiguous lateral ocelli and two micro-ocelli situated behind the lateral ocelli. Median longitudinal furrow throughout the length of carapace. Anterior margin with shallow emargination, finely granulated with conspicuous median notch. Lateral margins finely and densely crenulated below the lateral ocelli. Posterior margin finely crenulated.

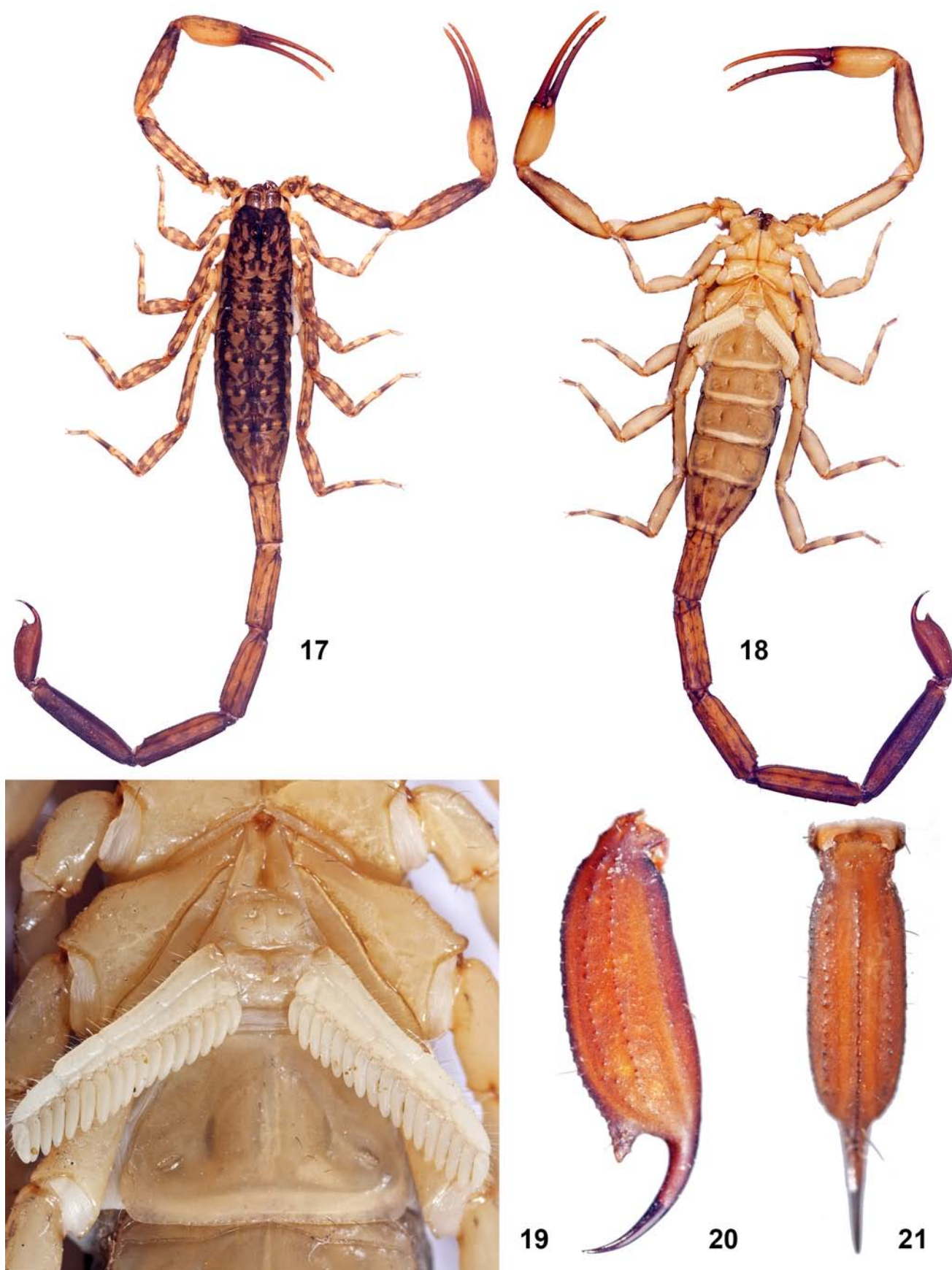
Chelicerae. Characteristic of the family Buthidae with normal buthid dentation on both fingers. Basal segments and movable fingers with short and firm setae on the basal and ventral surfaces.

Pedipalp (Figs. 27–31). Femur with 5 carinae (dorsal exterior, dorsal interior, exterior median, interior median, and exterior ventral). Exterior median carina with few granules more prominent, robust and triangularly tuberculate. All remaining carinae are evenly crenulated. Intercarinal space more granular on dorsal surface. Ventral surface almost smooth. Patella with 7 distinct carinae (dorsal median, dorsal interior, dorsal exterior, exterior median, ventral exterior, interior median and ventral interior). Dorsal median and dorsal interior carinae granular. Dorsal median present only on one-third distal portion. Dorsal exterior and exterior median almost smooth and obsolete. Intercarinal space weakly and sparsely granular. Interior median strongly tuberculated with few sub-denticulate granules. Both ventral carinae very weakly granular. Manus almost smooth, carinae weakly traceable. Fixed fingers with 2 smooth and obsolete carinae (dorsal exterior and dorsal interior). Dorsal

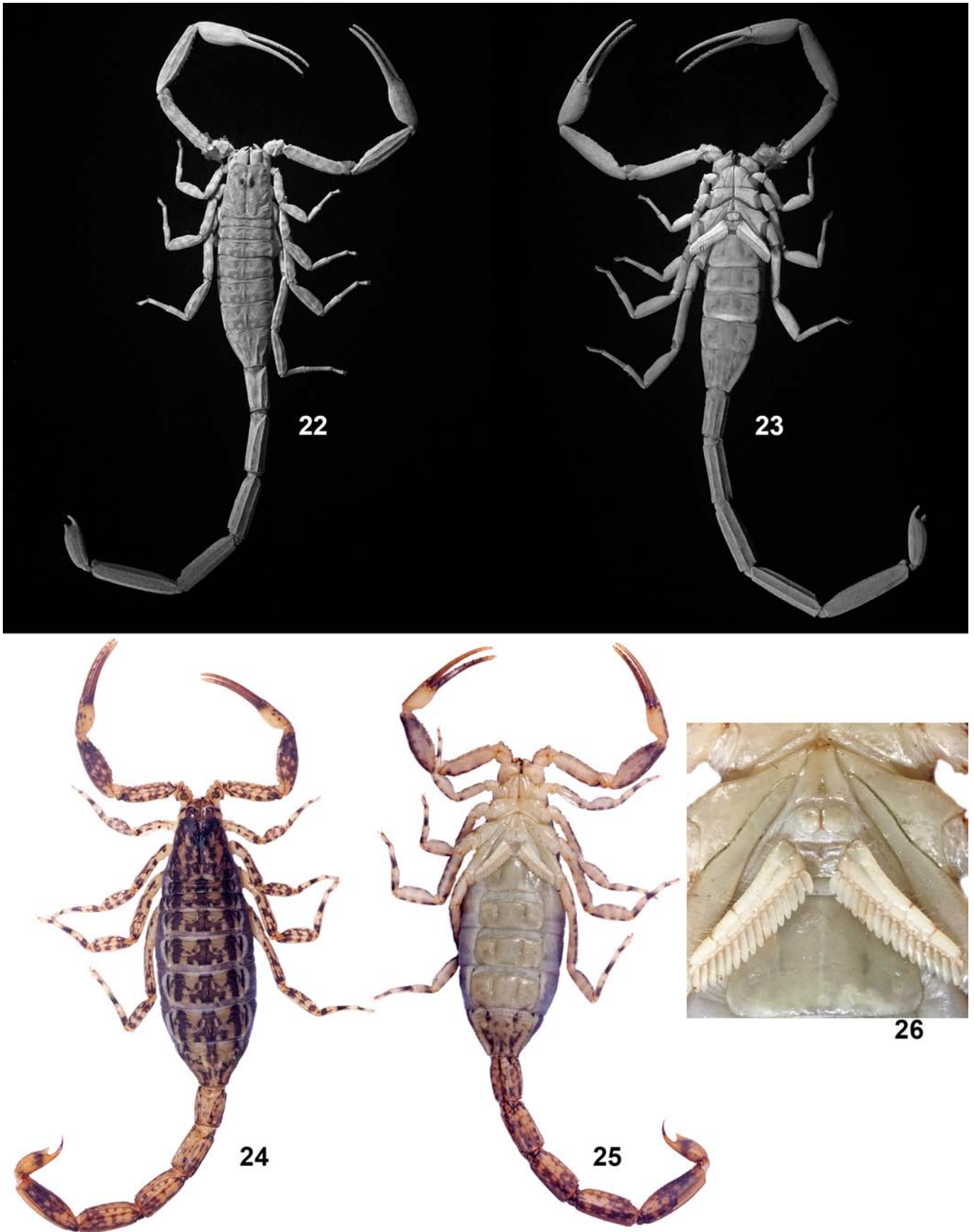
Dimensions (mm)		<i>I. amboli</i> sp. n. ♂ HT-BNHS SC157	<i>I. amboli</i> sp. n. ♂ PT-INHER42	<i>I. amboli</i> sp. n. ♂ PT-INHER111	<i>I. amboli</i> sp. n. ♂ PT-INHER110
Carapace	L / W	5.2 / 4.2	4.8 / 3.7	4.8 / 3.8	4.6 / 3.7
Mesosoma	L	14.9	12.6	14.0	14.5
Tergite VII	L / W	3.9 / 4.8	3.4 / 3.8	3.7 / 4.1	3.5 / 4.1
Metasoma + telson	L	44.3	38.8	38.1	37.0
Segment I	L / W / D	4.3 / 2.2 / 2.2	3.9 / 1.9 / 1.8	3.7 / 1.9 / 1.8	3.6 / 1.9 / 1.9
Segment II	L / W / D	5.6 / 1.9 / 2.0	4.7 / 1.6 / 1.7	4.8 / 1.7 / 1.8	4.7 / 1.6 / 1.8
Segment III	L / W / D	6.0 / 1.8 / 2.0	5.4 / 1.6 / 1.7	5.3 / 1.6 / 1.8	5.2 / 1.6 / 1.8
Segment IV	L / W / D	6.8 / 1.7 / 1.9	6.1 / 1.5 / 1.7	5.8 / 1.7 / 1.7	5.7 / 1.6 / 1.7
Segment V	L / W / D	8.2 / 1.9 / 2.0	6.8 / 1.5 / 1.8	7.0 / 1.6 / 1.8	6.5 / 1.5 / 1.7
Telson	L / W / D	6.7 / 1.6 / 1.9	6.0 / 1.4 / 1.6	5.7 / 1.5 / 1.7	5.7 / 1.3 / 1.6
Telson aculeus	L	2.4	2.2	2.3	2.1
Pedipalp	L	26.2	23.3	22.8	22.0
Femur	L / W	7.0 / 1.4	6.4 / 1.2	6.3 / 1.2	6.0 / 1.1
Patella	L / W	7.6 / 1.7	6.8 / 1.5	6.5 / 1.5	6.6 / 1.5
Chela	L	11.6	10.1	10.0	9.4
Manus	L / W / D	4.6 / 2.1 / 1.8	4.3 / 1.7 / 1.5	4.1 / 1.9 / 1.4	3.9 / 1.6 / 1.5
Movable finger	L	7.5	6.4	6.4	6.2
Pectine	L / W	4.2 / 0.9	3.7 / 0.9	4.1 / 0.8	3.6 / 0.8
Total	L	57.7	50.2	51.1	50.4

Dimensions (mm)		<i>I. amboli</i> sp. n. ♂ PT-INHER113	<i>I. amboli</i> sp. n. ♂ PT-INHER115	<i>I. amboli</i> sp. n. ♂ PT-INHER112	<i>I. amboli</i> sp. n. ♀ PT-BNHS SC158
Carapace	L / W	3.9 / 3.2	4.4 / 3.4	3.8 / 3.0	3.5 / 2.9
Mesosoma	L	12.4	12.0	10.8	10.2
Tergite VII	L / W	3.1 / 3.7	3.1 / 3.7	2.8 / 3.4	2.7 / 3.4
Metasoma + telson	L	29.7	30.5	28.0	21.1
Segment I	L / W / D	2.8 / 1.8 / 1.6	3.2 / 1.9 / 1.8	2.9 / 1.6 / 1.6	2.1 / 1.6 / 1.5
Segment II	L / W / D	3.7 / 1.5 / 1.5	4.0 / 1.6 / 1.7	3.7 / 1.4 / 1.6	2.4 / 1.5 / 1.5
Segment III	L / W / D	4.1 / 1.4 / 1.5	4.4 / 1.5 / 1.7	4.0 / 1.3 / 1.4	2.4 / 1.5 / 1.5
Segment IV	L / W / D	4.7 / 1.4 / 1.5	4.7 / 1.4 / 1.8	4.4 / 1.4 / 1.4	2.8 / 1.4 / 1.4
Segment V	L / W / D	5.1 / 1.3 / 1.5	5.6 / 1.5 / 1.7	4.8 / 1.3 / 1.5	3.5 / 1.3 / 1.4
Telson	L / W / D	4.7 / 1.4 / 1.2	4.3 / 1.3 / 1.4	4.2 / 1.2 / 1.3	3.9 / 1.1 / 1.1
Telson aculeus	L	1.7	1.9	1.7	1.6
Pedipalp	L	18.4	19.6	17.4	12.9
Femur	L / W	5.2 / 1.1	5.5 / 1.0	4.8 / 1.0	3.3 / 1.0
Patella	L / W	5.5 / 1.3	5.9 / 1.3	5.0 / 1.3	3.7 / 1.2
Chela	L	7.7	8.2	7.6	5.8
Manus	L / W / D	3.2 / 1.4 / 1.2	3.3 / 1.5 / 1.5	2.9 / 1.3 / 1.1	2.2 / 1.0 / 0.9
Movable finger	L	5.0	5.3	4.9	3.9
Pectine	L / W	3.1 / 0.7	3.0 / 0.7	3.1 / 0.6	2.4 / 0.6
Total	L	41.4	42.6	38.4	30.8

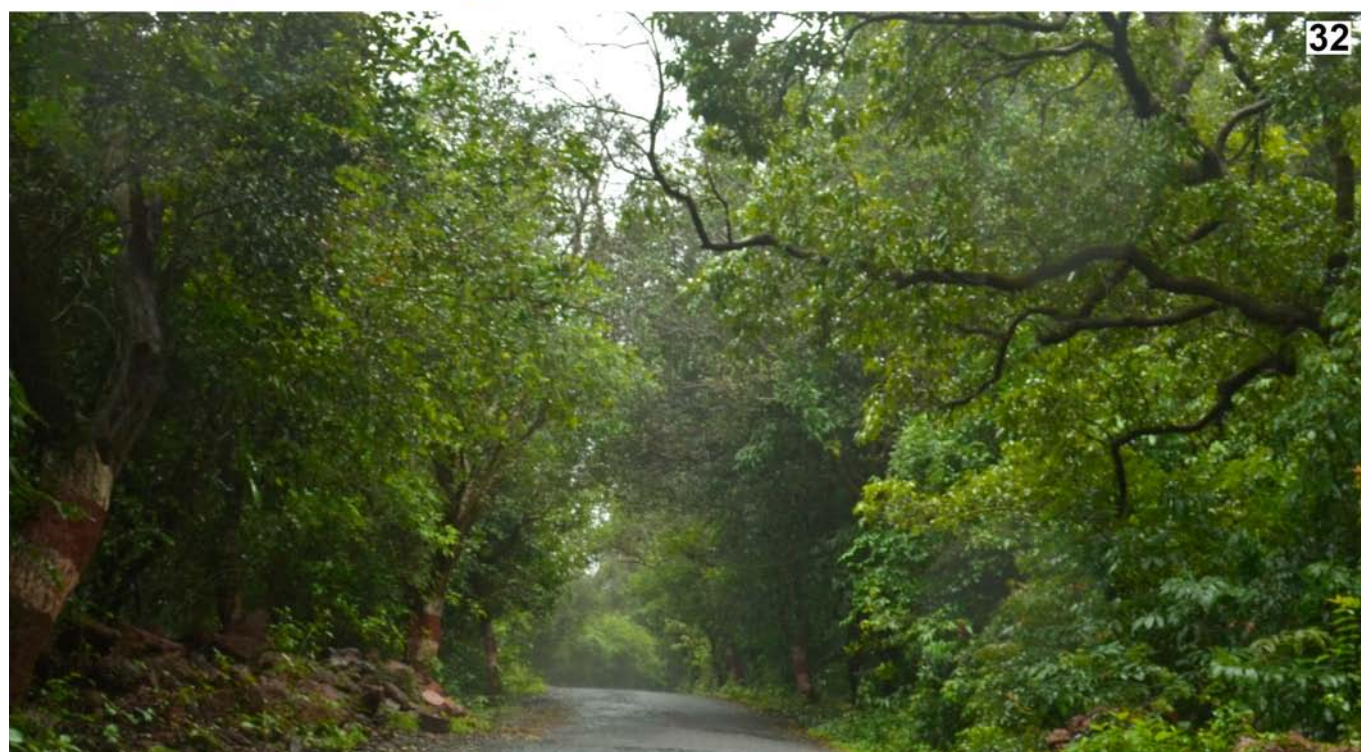
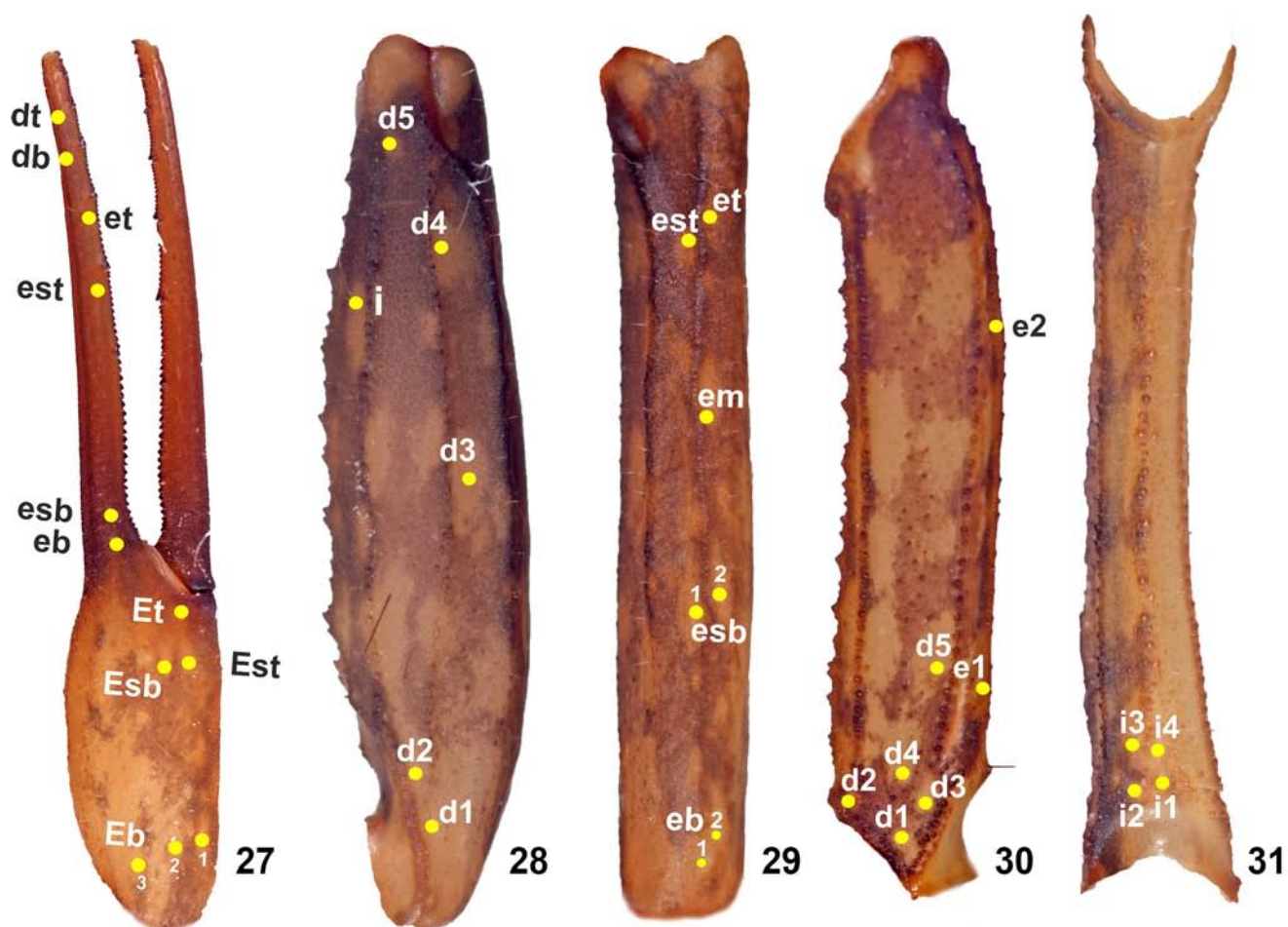
Table 1b: Morphometric data for *Isometrus amboli* sp. n. Abbreviations: length (L), width (W), depth (D), holotype (HT), paratype (PT).



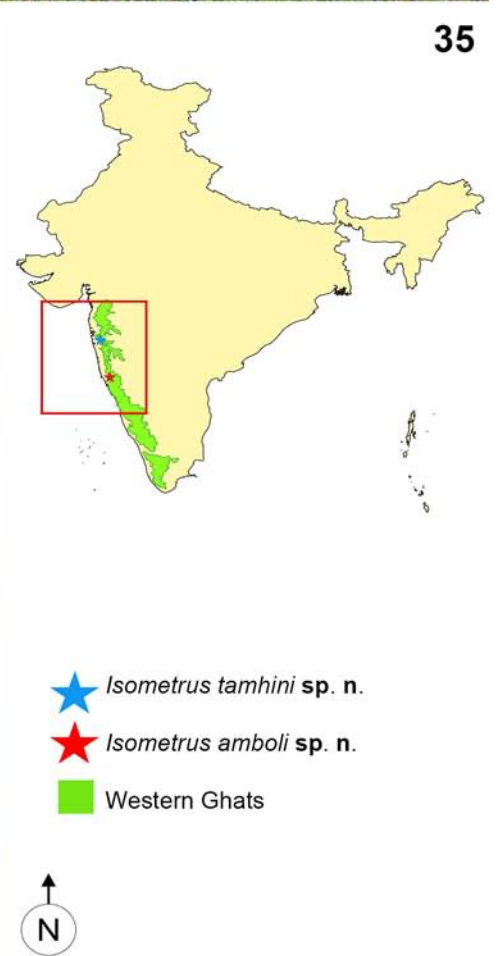
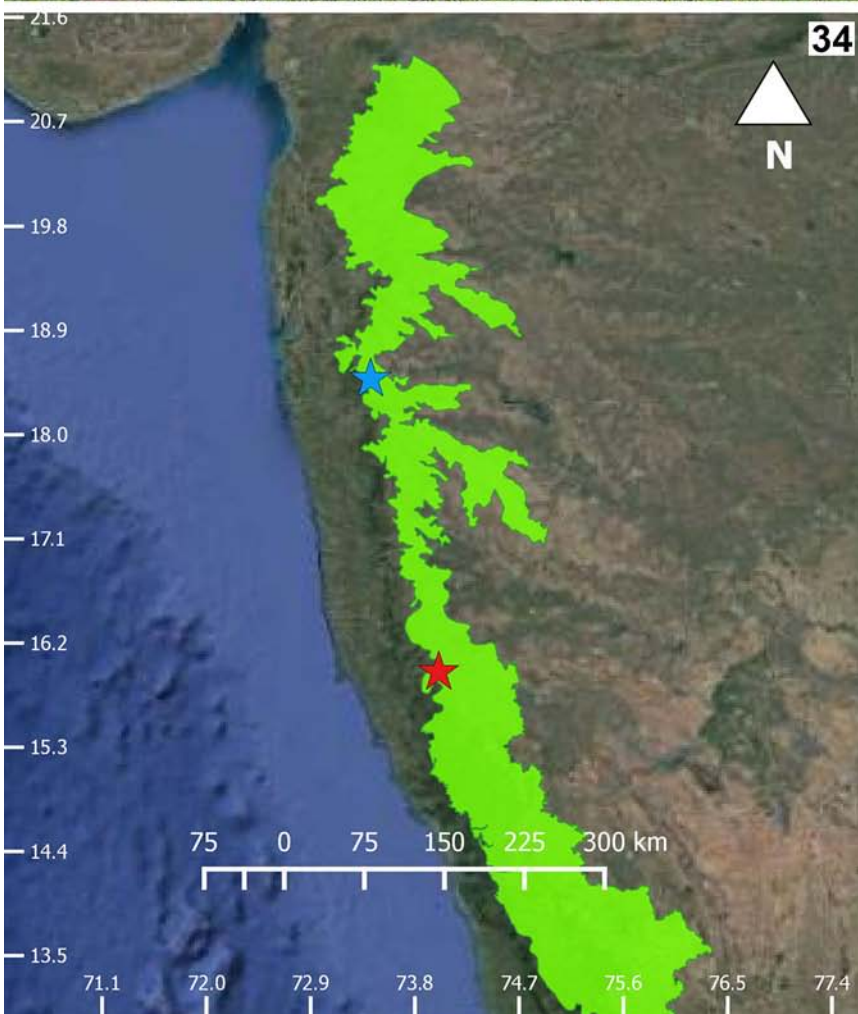
Figures 17–21: *Isometrus amboli* sp. n., male holotype **Figures 17–18.** Dorsal (17) and ventral (18) views **Figure 19.** Sternopectinal area. **Figures 20–21.** Telson in lateral (20) and ventral (21) views.



Figures 22–26: *Isometrus amboli* sp. n. **Figures 22–23.** Male holotype in dorsal (22) and ventral (23) views, UV image. **Figures 24–26.** Female paratype, BNHS-SC-158, in dorsal (24) and ventral (25) views, and sternoplectinal area (26).



Figures 27–32: *Isometrus amboli* sp. n. **Figures 27–31.** Male holotype, Pedipalp chela external (27), patella dorsal (28), and external (29), and femur in dorsal (30) and internal (31) view. Trichobothrial pattern indicated by yellow circles. **Figure 32.** Type locality of *I. amboli* sp. n., a dense semi-evergreen forest with tall trees.



Figures 33–35: Figure 33. Type locality of *I. amboli* sp. n., a dense semi-evergreen forest with tall trees. **Figures 34–35.** Type localities of *I. tamhini* sp. n. and *I. amboli* sp. n. from the northern Western Ghats of India.

Dimensions (mm)		<i>I. thurstoni</i> ♂ INHER134	<i>I. thurstoni</i> ♂ INHER136	<i>I. thurstoni</i> ♂ INHER141	<i>I. thurstoni</i> ♂ INHER139	<i>I. thurstoni</i> ♀ INHER130
Carapace	L / W	3.4 / 3.4	3.9 / 3.3	3.7 / 3.0	4.5 / 3.9	4.5 / 3.7
Mesosoma	L	10.8	11.4	10.8	10.4	13.4
Tergite VII	L / W	2.5 / 3.5	3.2 / 3.7	2.8 / 3.3	2.9 / 3.8	3.2 / 5.0
Metasoma + telson	L	26.1	30.9	29.4	37.1	30.4
Segment I	L / W / D	2.4 / 1.9 / 1.7	3.0 / 1.9 / 1.7	2.7 / 1.8 / 1.6	3.4 / 2.0 / 1.9	2.8 / 2.3 / 2.0
Segment II	L / W / D	3.1 / 1.6 / 1.7	3.8 / 1.6 / 1.7	3.4 / 1.6 / 1.6	4.3 / 1.8 / 1.9	3.5 / 1.9 / 2.0
Segment III	L / W / D	3.2 / 1.7 / 1.8	4.1 / 1.6 / 1.7	3.7 / 1.5 / 1.6	4.8 / 1.7 / 2.0	3.7 / 1.9 / 2.0
Segment IV	L / W / D	3.7 / 1.6 / 1.7	4.8 / 1.6 / 1.7	4.3 / 1.6 / 1.6	5.2 / 1.7 / 1.9	4.2 / 1.8 / 2.0
Segment V	L / W / D	4.6 / 1.6 / 1.7	1.6 / 1.6 / 1.7	5.2 / 1.5 / 1.6	7.2 / 1.8 / 1.9	5.4 / 1.7 / 2.0
Telson	L / W / D	4.6 / 1.2 / 1.2	5.3 / 1.3 / 1.5	5.1 / 1.3 / 1.4	6.1 / 1.6 / 1.7	5.4 / 1.4 / 1.6
Telson aculeus	L	1.9	1.9	2.0	2.3	2.3
Pedipalp	L	15.2	18.8	17.2	22.5	18.3
Femur	L / W	4.0 / 1.0	5.2 / 1.1	4.8 / 1.0	6.2 / 1.2	4.8 / 1.3
Patella	L / W	4.4 / 1.4	5.7 / 1.4	4.9 / 1.3	6.5 / 1.6	5.3 / 2.0
Chela	L	6.8	7.9	7.4	9.8	8.1
Manus	L / W / D	2.4 / 1.3 / 1.1	3.5 / 1.6 / 1.3	3.1 / 1.5 / 1.3	4.4 / 2.0 / 1.6	3.1 / 1.7 / 1.4
Movable finger	L	4.7	4.5	4.6	6.1	5.4
Pectine	L / W	3.0 / 0.6	3.2 / 0.7	3.1 / 0.7	3.5 / 0.7	3.0 / 0.7
Total	L	35.8	40.9	38.8	45.9	42.9

Dimensions (mm)		<i>I. thurstoni</i> ♀ INHER135	<i>I. thurstoni</i> ♀ INHER137	<i>I. thurstoni</i> ♂ CAS-1797.1	<i>I. thurstoni</i> ♀ INHER132
Carapace	L / W	4.3 / 4.4	4.9 / 4.3	5.1 / 5.1	3.7 / 3.3
Mesosoma	L	11.5	8.8	12.5	11.8
Tergite VII	L / W	2.7 / 5.0	2.8 / 4.5	-	2.8 / 4.0
Metasoma + telson	L	28.5	32.1	43.4	24.7
Segment I	L / W / D	2.8 / 2.3 / 2.1	2.7 / 2.4 / 2.2	4.1 / 2.1 / -	2.2 / 2.0 / 1.7
Segment II	L / W / D	3.5 / 2.0 / 2.0	3.4 / 2.1 / 2.2	5.0 / 2.0 / -	2.8 / 1.7 / 1.7
Segment III	L / W / D	3.8 / 2.0 / 2.1	3.9 / 2.1 / 2.1	5.3 / 1.9 / -	3.0 / 1.6 / 1.7
Segment IV	L / W / D	4.4 / 1.8 / 2.0	4.6 / 2.1 / 2.0	6.6 / 2.0 / -	3.4 / 1.7 / 1.6
Segment V	L / W / D	5.6 / 1.8 / 2.1	5.6 / 2.0 / 2.0	7.9 / 1.9 / -	4.3 / 1.5 / 1.6
Telson	L / W / D	4.2 / 1.6 / 1.5	6.0 / 1.6 / 1.6	7.3 / - / -	4.5 / 1.2 / 1.3
Telson aculeus	L	2.6	2.6	-	1.9
Pedipalp	L	19.2	19.8	18.1	15.4
Femur	L / W	5.0 / 1.4	5.1 / 1.4	6.3 / 1.4	4.0 / 1.4
Patella	L / W	5.5 / 2.0	5.7 / 1.9	7.0 / 1.9	4.4 / 1.6
Chela	L	8.8	8.9	-	7.1
Manus	L / W / D	3.1 / 1.7 / 1.5	3.2 / 1.9 / 1.5	4.9 / 2.5 / -	2.3 / 1.3 / 1.1
Movable finger	L	5.7	5.8	6.5	4.8
Pectine	L / W	3.1 / 0.8	3.3 / 0.8	3.8 / 0.6	2.7 / 0.5
Total	L	40.1	39.8	53.8	35.7

Table 1c: Morphometric data for *Isometrus thurstoni*. Abbreviations: length (L), width (W), depth (D).

exterior carina present all along the length. Fixed and movable finger armed with 5 rows of linear dentition Trichobothrial pattern typical for the genus .

Legs. Femur and patellae carinated. All carinae granular. Tibiae 3 and 4 without tibial spur. All legs with a pair of pedal spurs. Tarsomere covered with long delicate setae arranged in parallel

Dimensions (mm)		<i>I. maculatus</i> ♀ CAS 20.II.1962	<i>I. maculatus</i> ♀ CAS 21.II.1962	<i>I. maculatus</i> ♀ CAS 1.IV.1962	<i>I. maculatus</i> ♀ CAS IX-21-61	<i>I. maculatus</i> ♂ CAS-66- 486,6-10-66
Carapace	L / W	4.5 / 4.4	4.6 / 4.4	4.5 / 4.4	3.4 / 3.1	5.3 / 5.4
Mesosoma	L	15.1	13.8	11.3	8.1	13.1
Metasoma + telson	L	31.6	28.6	25.9	23.1	50.5
Segment I	L / W	2.6 / 2.1	2.6 / 2.0	2.9 / 2.0	2.1 / 1.6	5.0 / 2.3
Segment II	L / W	3.5 / 1.9	3.1 / 1.8	3.5 / 1.9	2.5 / 1.4	6.8 / 1.8
Segment III	L / W	3.9 / 1.8	3.4 / 1.6	3.5 / 1.8	2.9 / 1.3	7.3 / 1.8
Segment IV	L / W	4.6 / 1.6	3.9 / 1.6	4.4 / 1.6	3.8 / 1.3	8.8 / 1.6
Segment V	L / W	5.8 / 1.5	4.9 / 1.4	5.1 / 1.5	4.4 / 1.1	10.3 / 1.4
Telson	L	5.6	5.4	3.3	3.8	6.3
Pedipalp	L	12.0	12.2	11.9	9.3	24.0
Femur	L / W	4.5 / 1.0	4.6 / 1.0	4.3 / 1.1	3.1 / 0.9	9.4 / 1.3
Patella	L / W	4.9 / 1.3	4.9 / 1.5	5.0 / 1.5	3.9 / 1.1	10.0 / 1.5
Manus	L / W	2.6 / 1.5	2.8 / 1.5	2.6 / 1.4	2.3 / 1.3	4.6 / 1.6
Movable finger	L	4.4	5.1	5.0	3.9	8.3
Pectine	L / W	2.6 / 0.5	2.6 / 0.5	3.4 / 0.4	2.4 / 0.4	4.4 / 0.6
Total	L	45.6	41.5	38.4	32.1	62.6

Table 1d: Morphometric data for *Isometrus maculatus*. Abbreviations: length (L), width (W).

Ratios of specimens	<i>I. amboli</i> sp. n.	<i>I. tamhini</i> sp. n.	<i>I. maculatus</i>	<i>I. thurstoni</i>
	7♂, 1♀	3♂, 4♀	1♂, 4♀	5♂, 4♀
Pedipalp / Carapace (L) ♂	4.5-5	5.1-5.4	4,6	3.5-5.0
Pectine (L/W) ♂, ♀	3.9-5.0	3.9-4.7	5.2-9.0	4.1-6.0
Telson (L/D) ♂, ♀	3.2-3.8	4.0-4.1	-	3.5-3.7
Telson / Telson Aculeus (L) ♂	1.9-2.8	3.0-3.4	-	2.5-2.7
Total length ♂, ♀	30.8-57.7	35.4-58.4	32.1-62.6	35.7-53.8

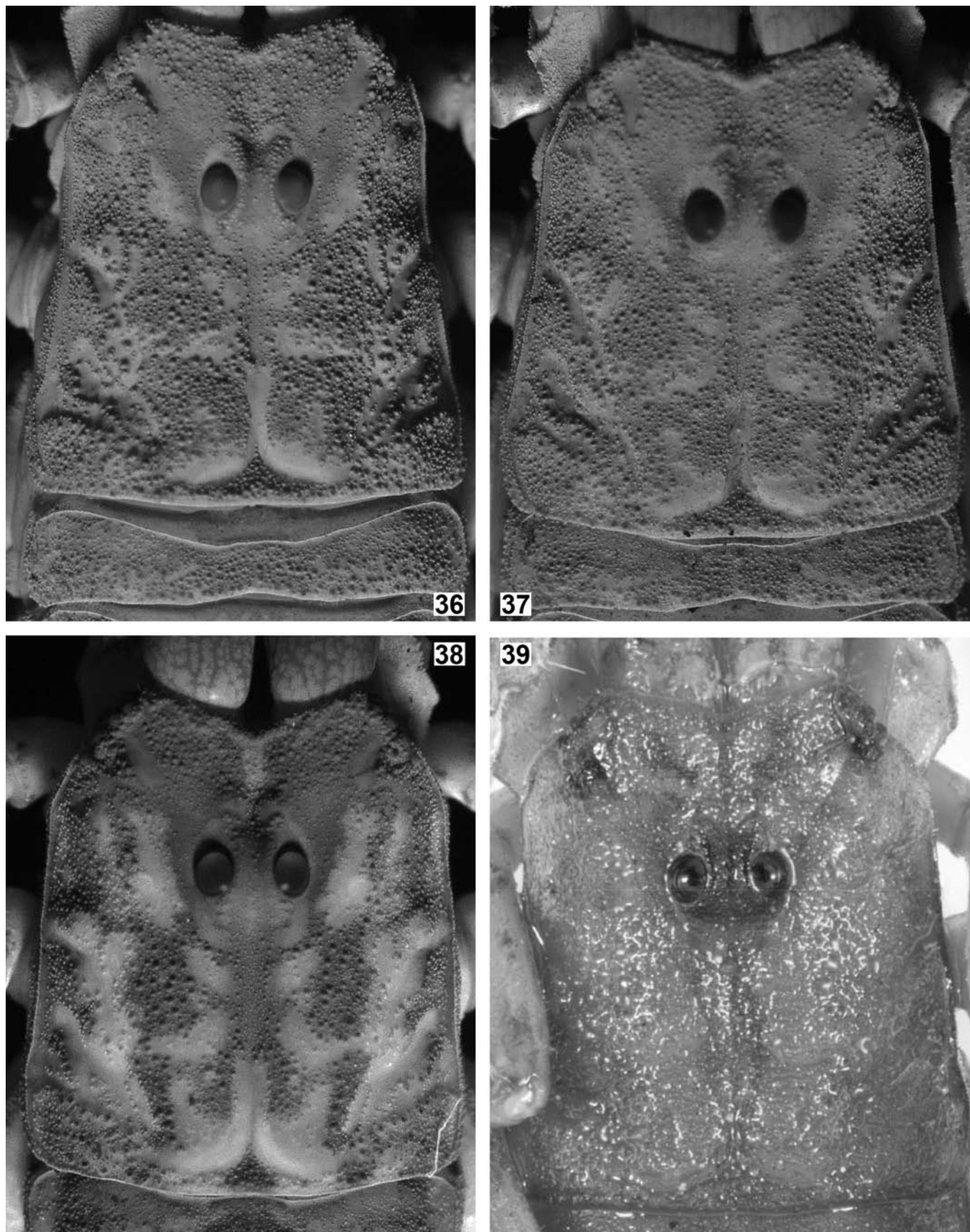
Table 1e. Comparison among *Isometrus* species based upon selected morphometric ratios of adults. Abbreviations: length (L), width (W), depth (D).

rows on ventral side. Tarsomere I provided with tuft of short, stout blackish setae. Tarsomere II compressed laterally. Dorsal margin of each leg ending into a pointed projection and ventrally provided with paired row of short, pointed, anteriorly directed, closely placed setae. Tarsomere II armed with a pair of sharply pointed curved claws and a soft, triangular and blunt basal claw. **Genital operculum** (Figs. 19, 26). Wider than long, elliptical, separated with a pair of short male genital papillae, with a few reddish setae present on lateral posterior portion.

Pectines (Figs. 19, 26). Basal piece squarish, deeply notched on anterior median margin. Posterior margin of basal piece straight; smooth on surface with a parallel narrow sub-basal piece along the posterior margin. Surface provided with pairs of short, red setae. Pectine 4.6 times longer than its width, marginal lamella of 3 digits and median lamella of 6 digits, external margin armed with a row of stout short red setae and few setae on surface. Fulcra 16, roughly triangular each armed with few short red setae, placed in between adjacent pectinal teeth. Teeth 17, strong and stout.

Mesosoma (Figs. 17–19, 22–25). Tergites I–VI densely and finely granular, with a granular median carina. Posterior and lateral margins granular. Tergite VII narrowed posteriorly, granular, with 2 pairs of lateral granular carinae, inners up to pre-tergal portion while outer pair runs diverging laterally up to two-thirds portion and end abruptly. A broad median carina limited to anterior two-thirds of median portion. Sternites III–VI almost entirely smooth with a pair of spiracles. Margins smooth, each tergite with different numbers of setae on surface and posterior margins. Sternite V with extended, convex and exceptionally smooth posterior median margin. Sternite VII smooth on posterior margin while finely crenulated to serrated on lateral margins; with 2 pairs of granular carinae; median carinae restricted to posterior two-thirds portion; lateral carinae present in the middle portion.

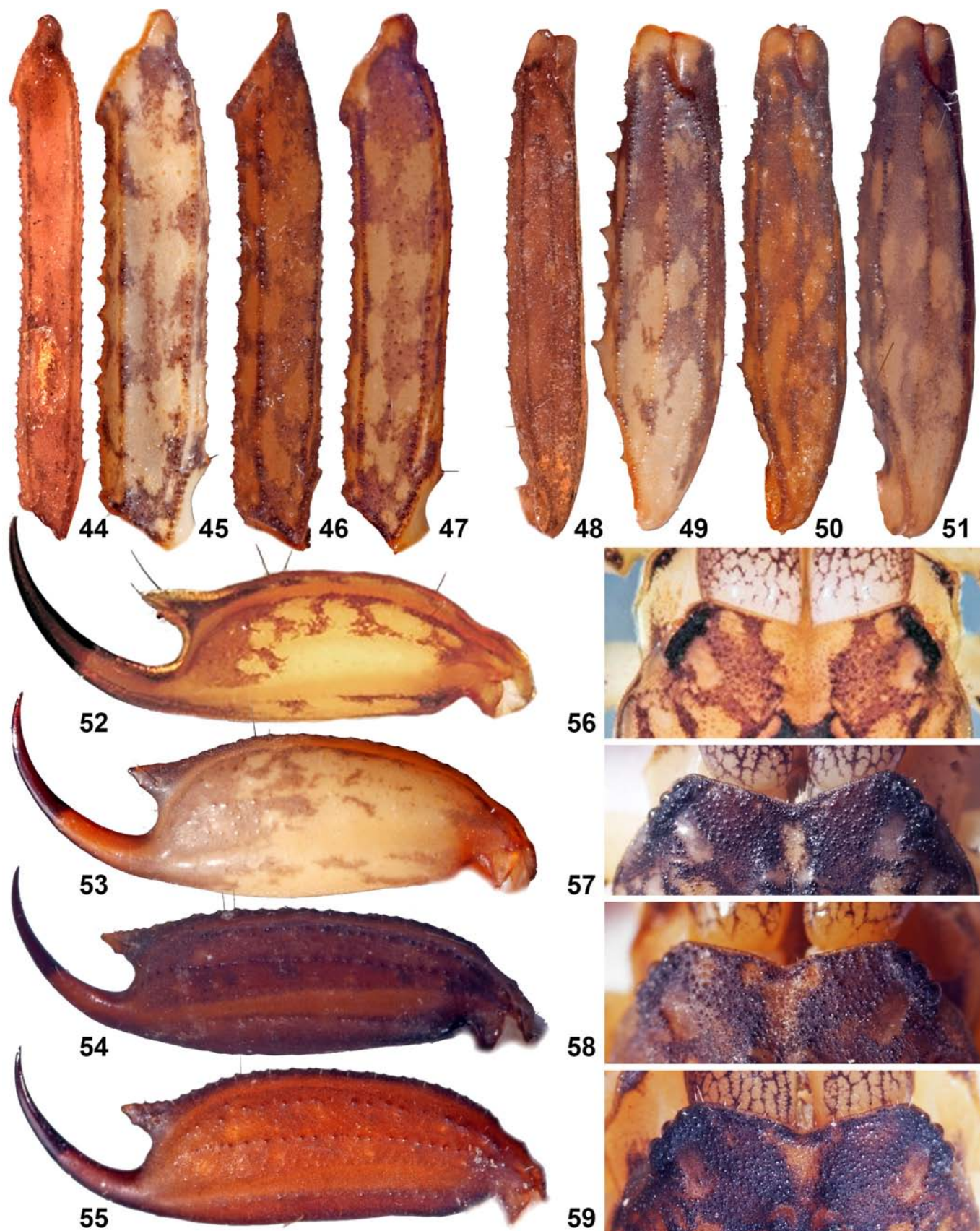
Metasoma (Figs. 17–18, 22–25). All segments longer than wide; basal segment two times longer than wide. Segment I with 5 pairs of carinae (dorsals, dorsolaterals, laterals, ventrolaterals and ventrals) well developed and granular,



Figures 36–39: Comparative surface granulation of carapace. **Figure 36.** *Isometrus tamhini* sp. n., male, holotype. **Figure 37.** *I. amboli* sp. n., male, holotype. **Figure 38.** *I. thurstoni*, male, INHER-SC-139. **Figure 39.** *I. maculatus*, male, CAS-66-486 (photo by Shruti Paripatyadar).



Figures 40–43: Comparative color pattern on carapace. **Figure 40.** *Isometrus tamhini* sp. n., male, holotype. **Figure 41.** *I. amboli* sp. n., male, holotype. **Figure 42.** *I. thurstoni*, male, INHER-SC-139. **Figure 43.** *I. maculatus*, male, Cuba (photo by Rolando Teruel)



Figures 44–59: Figures 44–47: Comparison of pedipalp femur, dorsolateral view. Figures 48–51: Comparison of pedipalp patella, dorsolateral view, Figures 52–55: Comparison of telson, lateral view. Figures 56–59: Comparison of anterior margins of carapace. Figures 44, 48, 52, 56. *I. maculatus*, male, CAS-66-486 (44, 48, photos by Shruti Paripatyadar). and male from Cuba (52, 56 photos by Rolando Teruel). Figures 45, 49, 53, 57. *I. thurstoni*, male, INHER-SC-139. Figures 46, 50, 54, 58. *I. tamhini* sp. n., male, holotype. Figures 47, 51, 55, 59. *I. amboli* sp. n., male, holotype.

Variables	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8
Total length	0,687	-0,249	-0,664	0,128	-0,047	0,026	-0,004	0,004
Carapace Length	0,036	-0,038	-0,021	0,004	0,415	0,241	-0,172	-0,084
Carapace Width	0,030	-0,078	0,012	0,029	0,733	-0,350	-0,175	0,108
Pedipalp Length	0,352	0,925	0,019	0,040	0,045	-0,085	-0,055	-0,054
Mesosoma Length	0,561	-0,242	0,627	-0,309	-0,105	-0,075	-0,283	-0,059
Metasoma I Length	0,059	-0,006	0,071	0,119	-0,035	0,119	-0,045	-0,157
Metasoma II Length	0,081	-0,024	0,083	0,214	-0,094	0,073	0,029	-0,045
Metasoma III Length	0,089	-0,026	0,111	0,169	-0,157	0,137	-0,016	0,113
Metasoma IV Length	0,107	-0,033	0,129	0,144	-0,093	-0,297	-0,013	0,100
Metasoma V Length	0,124	-0,088	0,123	0,076	0,211	-0,404	0,682	-0,344
Pedipalp Femur Length	0,108	0,008	0,163	0,248	-0,008	0,156	0,320	0,529
Pedipalp Patela Length	0,108	-0,018	0,195	0,282	0,088	0,078	0,215	0,457
Pedipalp Manus Length	0,070	0,028	0,054	-0,162	-0,093	0,233	0,346	-0,331
Movable Finger Length	0,079	-0,005	0,144	0,215	0,378	0,596	-0,017	-0,213
Pectine Length	0,037	-0,035	0,095	0,083	-0,005	0,175	0,174	-0,228
Telson length	0,081	0,060	-0,106	-0,742	0,165	0,214	0,299	0,334
Eigenvalue	146,483	5,249	1,387	0,469	0,297	0,155	0,108	0,086
% variance	94,873	3,399	0,899	0,304	0,192	0,101	0,070	0,056
Cumulative eigenvalue	146,483	151,732	153,119	153,588	153,885	154,040	154,148	154,234
Cumulative % variance	94,873	98,272	99,171	99,475	99,667	99,768	99,837	99,893

Variables	PC 9	PC 10	PC 11	PC 12	PC 13	PC 14	PC 15	PC 16
Total length	-0,011	0,009	-0,026	-0,046	-0,037	-0,004	-0,020	-0,019
Carapace Length	0,218	-0,283	-0,081	0,739	-0,021	-0,171	-0,093	0,107
Carapace Width	0,288	0,028	-0,062	-0,336	0,106	0,225	0,165	-0,009
Pedipalp Length	-0,015	0,006	-0,044	0,020	-0,001	-0,004	0,016	-0,017
Mesosoma Length	-0,104	-0,071	-0,135	-0,033	0,001	-0,048	-0,023	-0,019
Metasoma I Length	0,215	-0,057	0,398	-0,020	0,522	0,166	-0,426	-0,495
Metasoma II Length	0,134	0,132	0,107	-0,032	0,627	-0,364	0,395	0,440
Metasoma III Length	0,062	-0,045	0,205	0,272	-0,084	0,562	0,643	-0,192
Metasoma IV Length	0,290	0,349	0,502	0,174	-0,313	0,092	-0,291	0,405
Metasoma V Length	-0,311	-0,076	0,079	0,214	0,057	-0,001	0,051	-0,069
Pedipalp Femur Length	-0,046	-0,214	-0,320	-0,013	0,196	0,345	-0,322	0,285
Pedipalp Patela Length	0,164	0,001	0,103	-0,070	-0,251	-0,549	0,107	-0,428
Pedipalp Manus Length	0,577	-0,397	0,020	-0,316	-0,229	0,031	0,053	0,161
Movable Finger Length	-0,398	0,171	0,264	-0,247	-0,188	0,056	-0,046	0,158
Pectine Length	0,299	0,684	-0,508	0,117	-0,010	0,095	-0,042	-0,167
Telson length	0,004	0,252	0,240	0,082	0,152	0,021	0,056	0,004
Eigenvalue	0,061	0,035	0,027	0,019	0,012	0,005	0,004	0,003
% variance	0,040	0,023	0,018	0,012	0,007	0,003	0,002	0,002
Cumulative eigenvalue	154,295	154,331	154,358	154,377	154,388	154,393	154,396	154,399
Cumulative % variance	99,933	99,956	99,973	99,985	99,993	99,996	99,998	100,000

Table 2: Factor loadings, eigenvalues and percent variance from Principal component analysis (PCA) for adult specimens of *Isometrus maculatus*, *I. thurstoni*, *I. tamhini* sp. n., and *I. amboli* sp. n.

Species	% correct	<i>I. maculatus</i>	<i>I. thurstoni</i>	<i>I. tamhini</i>	<i>I. amboli</i>	Total
<i>Isometrus maculatus</i>	100	5	0	0	0	5
<i>Isometrus thurstoni</i>	100	0	9	0	0	9
<i>Isometrus tamhini</i> sp. n.	100	0	0	7	0	7
<i>Isometrus amboli</i> sp. n.	100	0	0	0	8	8
Total	100	5	9	7	8	29

Table 3: Classification matrices from the discriminant function analysis.

Variables	DFA Axis 1	DFA Axis 2	DFA Axis 3
PC 1	0.04712	-0.00748	0.01434
PC 2	0.77275	-0.05823	-0.24785
PC 3	0.00203	0.02851	-0.59056
PC 4	1.0063	-0.41151	1.94
PC 5	-1.6791	-1.3525	-1.0227
PC 6	4.64	3.087	-0.64499
PC 7	-3.767	3.7042	0.42946
PC 8	-2.5551	-0.09056	0.02049
PC 9	-1.5631	2.0895	0.81994
PC 10	-2.0621	2.2966	1.087
PC 11	5.7348	-1.7137	1.091
PC 12	4.5169	-2.518	5.6638
PC 13	7.2508	-3.2018	-2.6797
PC 14	4.5457	1.6251	5.0773
PC 15	7.4663	5.4014	-2.2318
PC 16	6.997	0.12021	2.215
Eigenvalue	13.466	4.1932	2.7068
Cumulative %	66.12	20.59	13.29

Table 4: Scores for discriminant function analysis of principal components resulting from morphometric measurements of *Isometrus maculatus*, *I. thurstoni*, *I. tamhini* **sp. n.**, and *I. amboli* **sp. n.**

ending posteriorly in a sub-triangular blunt and weakly pointed tubercle. Intercarinal space weakly and sparsely granular, anterior margin granular. Segments II and III with 4 pairs of carinae (dorsal, dorsolateral, ventrolaterals and ventrals). Laterals granular and marked on posterior one-third portion of II and III segments. Intercarinal portion weakly and finely granular, dorsolateral and dorsal carinae posteriorly ending in to subtriangular tubercles. Segment IV with 4 pairs of granular carinae (dorsal, dorsolateral, ventrolaterals and ventrals). Dorsals ending into subtriangular tubercles. Intercarinal space less irregularly granular. Segment V with 7 carinae (dorsal, dorsolateral and ventrolateral pairs and single ventral); dorsal carinae granular. Dorsolaterals present throughout. Laterals present on anterior one-fourth portion. Ventrolaterals and single ventral median carinae weakly granular and ending posteriorly into granular anal rim. Intercarinal space irregularly, weakly and finely granular than segments I to IV.

Telson (Figs. 20–21, 55) Vesicle elongated, less carinated; smooth and flat on dorsal surface. Lateral surface demarcated with granular ridge. Ventral median carina finely granular and

ending posteriorly into triangular, subaculear tooth, on inner margin with minute denticle. Ventral portion with two pairs of sparsely and finely granular carinae. Intercarinal space weakly and finely granular. Aculeus with acute angle between subaculear nodule and base of aculeus. Subaculear tooth pointed and external margin along the ventral median carina angular with the vesicle.

SEXUAL DIMORPHISM. Male genital operculum partially exposed on posterior portion, from which a pair of small genital papillae is seen. In females, the genital operculum is separated with a median suture covering the female genital orifice (Figs. 19, 26).

AFFINITIES. *Isometrus amboli* **sp. n.** is distinguished from its congeners based on the following set of characters: **1)** Surface of carapace densely and finely granular as opposed to densely and coarsely granular in *I. tamhini* **sp. n.**, granular throughout but obsolete in *I. maculatus*, as opposed to sparsely granular with some areas without granules in *I. thurstoni*. (Figs. 36–39). **2)** External margin of subaculear tooth of telson along the ventral median carina, angular with the vesicle (Fig. 20). **3)** Pedipalp length less than or equal to 5 times the carapace length in males as opposed to more than 5 times in males of *I. tamhini* **sp. n.** (Table 1e). **4)** Anterior margin of carapace with shallow emargination as opposed to anterior margin of carapace with deep emargination in *I. thurstoni* (Figs. 56–59). **5)** Telson depth to telson length ratio is less than four times in males as opposed to more than four times in *I. tamhini*. (Table 1). **6)** Telson aculeus more elongated in males (telson length always less than 3 times telson aculeus length) as opposed to telson aculeus less elongated in males (telson length 3 times or more than 3 times telson aculeus length) in *I. tamhini* **sp. n.** (Table 1e, Figs. 52, 53, 55). **7)** Ventral median carina on vesicle strongly granular as opposed to very weakly granular in *I. thurstoni* (Fig. 21). **8)** Pectine length less than or equal to 5 times pectine width as opposed to pectine length greater than 5 times pectine width in *I. maculatus* in males and females (Table 1e).

DISTRIBUTION, HABITAT AND ECOLOGY. The new species is currently known only from the type locality. In our primary surveys, it was found on tall trees in the semi-evergreen forests of Amboli. All specimens were found on the bark of trees with ridges, at a height from 2–4 meters. A few specimens were also collected from inside the tree holes (Figs. 32–35).

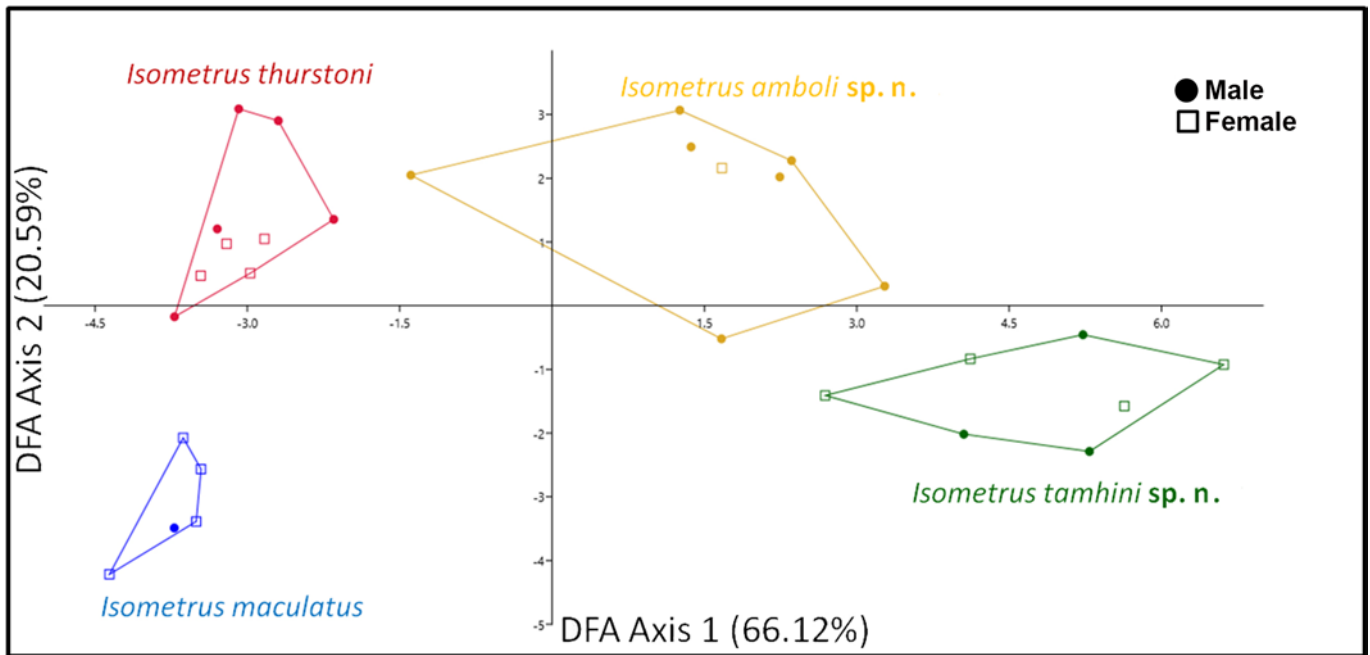


Figure 60: Discriminant function analyses (DFA) projection on first two factor planes explaining 86.71% of variation among the four species.

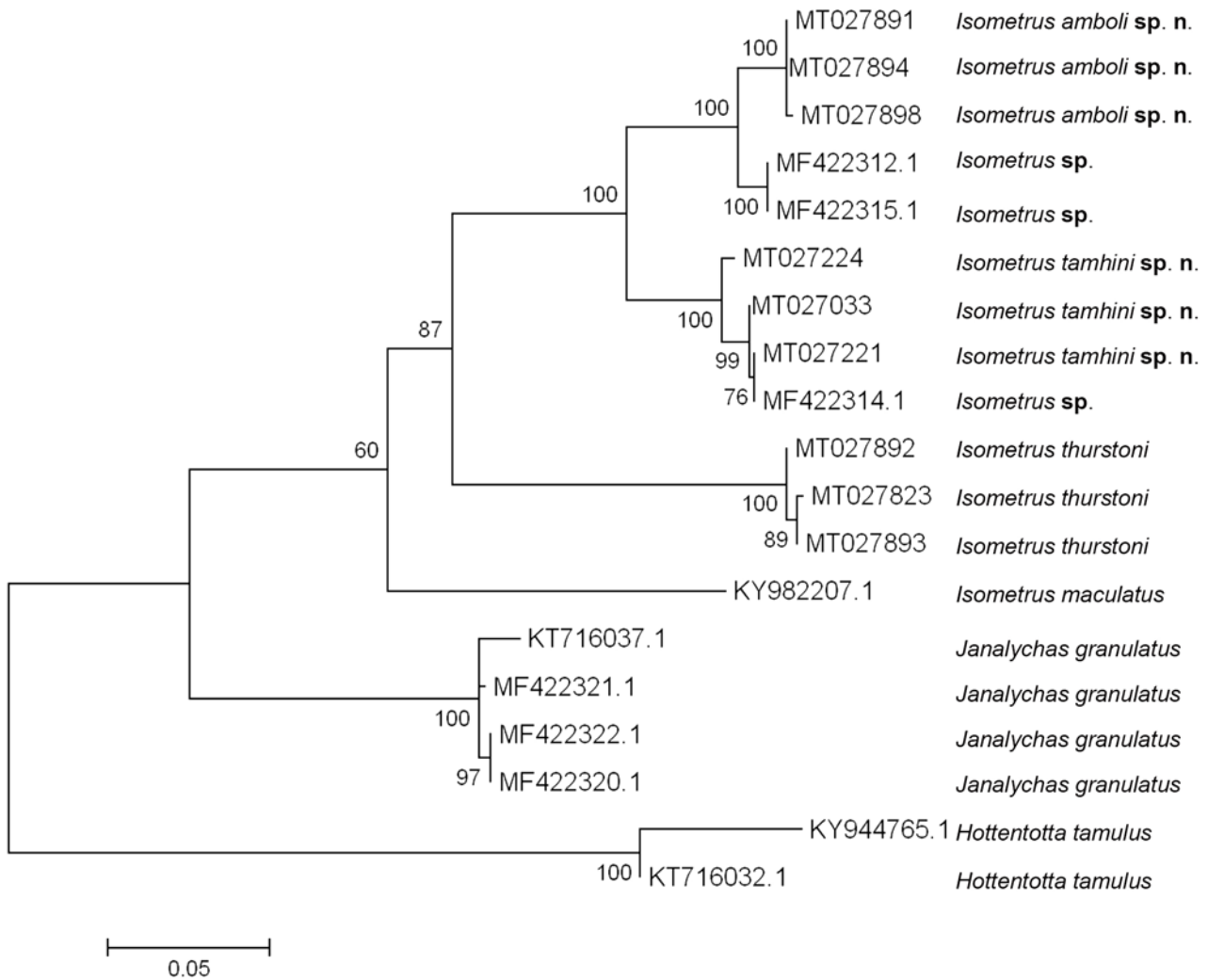


Figure 61: Maximum likelihood (ML) phylogeny of the Indian *Isometrus*. Values along the nodes are % bootstraps for 1000 iterations.

Species	IM	ITH	ITM	IAM
<i>Isometrus maculatus</i> (IM)	0			
<i>Isometrus thurstoni</i> (ITH)	13.7-14.2	(0.2-0.5)		
<i>Isometrus tamhini</i> sp. n. (ITM)	13.5-13.7	11.6-12.4	(0.2-1.2)	
<i>Isometrus amboli</i> sp. n. (IAM)	13.4	13-13.2	6.6-7.4	(0-0.2)

Table 5: Pairwise uncorrected raw distances (%) expressed as minimum–maximum based on COI gene sequence for *Isometrus* species. Values in brackets are intra-clade distances.

Species	Voucher	GeneBank Accession Number
<i>Isometrus tamhini</i> sp. n.	BNHSC SC 155	MT027221
<i>Isometrus tamhini</i> sp. n.	BNHS SC 156	MT027224
<i>Isometrus tamhini</i> sp. n.	INHER 73	MT027033
<i>Isometrus amboli</i> sp. n.	BNHS SC 157	MT027898
<i>Isometrus amboli</i> sp. n.	BNHS SC 158	MT027894
<i>Isometrus amboli</i> sp. n.	INHER 111	MT027891
<i>Isometrus thurstoni</i>	INHER 141	MT027893
<i>Isometrus thurstoni</i>	INHER 139	MT027823
<i>Isometrus thurstoni</i>	INHER 130	MT027892

Table 6: Voucher numbers and GenBank accession numbers for the sequence data used for the phylogenetic analysis.

Statistical Analysis

The first three PCA factors with eigenvalues more than 1.0 explained 99.17% of variation among the species (Table 2). The DFA using all the PCA factors as input resulted in 100% of individuals being classified into their respective species (Table 3). The three discriminant functions with eigenvalues greater than 1.0 explained 100% of variation among these species (Table 4), all the species formed distinct clusters on the factor plane using the first two DFA axes (Fig. 60).

Genetic Analysis

The model selection suggested transition model with gamma distribution (HKY+I, $\ln L = -2272.654$, $df = 40$, $BIC = 4915.361$) as the best nucleotide substitution model. *Isometrus tamhini* sp. n. and *I. amboli* sp. n. formed a monophyletic clade distinct from *I. maculatus* and *I. thurstoni* in maximum likelihood analysis (Fig. 61). *I. tamhini* sp. n. differed from *I. maculatus* by a raw genetic distance of 13.5–13.7%, and from *I. thurstoni* by 11.6–12.4%. *I. amboli* sp. n. differed from *I. maculatus* by a raw genetic distance of 13.4 %, and from *I. thurstoni* by 13.0–13.2% (Table 5). *I. tamhini* sp. n. and *I. amboli* sp. n. differ from each other by a raw genetic distance of 6.6–7.4% (Table 5).

Discussion

The distribution records of the genus *Isometrus* from India (under *I. maculatus* and *I. thurstoni*) were last listed by Kovařík (2003), based on older museum collections. Though *Isometrus maculatus* has been reported from the

state of Maharashtra, none of our collected specimens from the northern Western Ghats matched *I. maculatus* morphologically and genetically. The COI gene sequence KY982207.1 (Esposito et al., 2018) of *I. maculatus* from Wellawaya, Sri Lanka, used for comparison, is the only available DNA sequence of this species.

The species of the genus *Isometrus* are morphologically cryptic and the specimens that we collected and studied in the museum collections are difficult to distinguish based on morphology alone. In our DNA-based phylogeny, *I. tamhini* sp. n. and *I. amboli* sp. n. form a different clade and, among the Indian species, are closer to *I. thurstoni* than to *I. maculatus*.

Other sequences available in GenBank (MF422312.1 and MF422315.1) (Dahanukar & Suranase, unpublished) of unidentified *Isometrus* species from Ajara near Amboli are similar to the sequences of *I. amboli* sp. n. with a raw genetic distance of 2.3–2.5%; therefore we consider this population to belong to *I. amboli* sp. n. Also, a gene sequence MF422314.1 obtained by Dahanukar & Suranase (unpublished) of unidentified *Isometrus* species from Tamhini belongs to *I. tamhini* sp. n.

A type specimen of *I. maculatus* from DeGeer's collection exists in the Swedish Royal Museum of Natural History, Stockholm (V. Fet, pers. comm); however, its type locality is undefined (it was originally listed as "Suriname and Pennsylvania"); this cosmopolitan species is assumed to have originated from South Asia (Fet & Lowe, 2000). Assignment of specimens collected worldwide to *I. maculatus* was made traditionally based on morphology. Considering the origin, presence and dispersal of *I. maculatus* around the world (Fet & Lowe, 2000; Lourenço & Huber, 2002; Kovařík & Ojanguren, 2013; Veronika et al., 2013; Kovařík et al., 2016), and the records of *I. maculatus* and *I.*

thurstoni in more than five states in India (Kovářík, 2003), it is imperative to follow integrated taxonomy to achieve clarity regarding distribution of these species. With our description of two new species from the northern Western Ghats, it is apparent that the genus *Isometrus* might have more undescribed species in India.

Considering the high faunal diversity in the Western Ghats biodiversity hotspot and the associated threats to the same, it is essential to understand the diversity through discovery of undescribed species as well as distribution pattern and delimitation of the species so as to set priorities and appropriate strategies for conservation.

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